INVESTIGATION OF TIDAL POWER

Cobscook Bay Maine

ENVIRONMENTAL APPENDIX

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Division

AUGUST 1980

Investigation of Tidal Power
Cobscook Bay, Maine

ENVIRONMENTAL APPENDIX

August 1980

U.S. Army Engineer Division, New England
424 Trapelo Road
Waltham, Massachusetts 02254

PREFACE

This appendix is comprised of the following reports prepared in support of the Corps of Engineers reconnaissance report for the Cobscook Bay Tidal Power Project:

U.S. Fish and Wildlife Service, Planning Aid Report, October, 1979.

National Marine Fisheries Service, Northeast Region, Environmental Assessments and Evaluations, January, 1980.

Habitat Utilization By Southward Migrating Shorebirds in Cobscook Bay, Maine during 1979, Project Report, School of Forest Resources, University of Maine, Orono, June, 1980.

Social and Cultural Resource Appendix.

Water Quality Report

Additionally, pertinent tables have been extracted from the Draft Ecological Characterization Study of Coastal Maine, prepared by the U.S. Fish and Wildlife Service, Office of Biological Services, Region 5. This characterization study divided the coast of Maine into 6 separate regions. Region 6 encompasses Washington County which includes the Cobscook Bay area.

Contents of Appendix

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
P.O. Box 1518
Concord, New Hampshire 03301

OCT 0 2 1979

Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

Enclosed is our planning aid report on your Cobscook Tidal Power Project. It is being sent in response to Dr. Bud Barrett's request for Fish and Wildlife Service input to a generic environmental impact assessment of the project.

Sincerely yours,

Gordon E. Beckett
Supervisor

Enclosure

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
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Ref: 305-12

OCT 02 1979

COBSCOOK BAY TIDAL POWER PROJECT
MAINE

Planning aid report by the U.S. Fish and Wildlife Service on a plan being developed for power generation and other purposes by the New England Division, U.S. Army Corps of Engineers.

Gordon W Russell
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Fishery Biologist

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Supervisor

PREFACE

The Corps of Engineers survey investigation of the Cobscook Tidal Power Project was authorized by a resolution of the Committee on Public Works of the United States Senate, dated March 21, 1975. It called for a determination of the current feasibility of the Passamaquoddy Tidal Power Project in the interest of providing tidal power, recreation, economic development and related land and water resource purposes. The survey investigation is currently at the end of Stage I planning, where it will be reportedly terminated because it currently lacks economic feasibility.

The purpose of this fish and wildlife report is to express FWS's preliminary views on the tidal power project. It will be updated should the Corps resume their survey investigation. Authority for this report is the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

I. Description of the Project

As authorized by Senate resolution the Corps study was intended to re-examine the Passamaquoddy Tidal Power Project. International in scope, the Quoddy project involved both Passamaquoddy Bay in New Brunswick, Canada and Cobscook Bay in Washington County, Maine. The Canadian Government has since declined to participate in an international project. Therefore, the present study involves an all-American project and will be referred to as Cobscook Tidal Power Project.

The Cobscook Tidal Power Project calls for construction of dams that would impound all, or portions of Cobscook Bay, Maine. Most of the alternative dam alignments would result in a single pool. During routine operation the pool would fill via gates during flood tide. Water would be held behind the dam through part of the ebb until sufficient head was developed, at which time it would be discharged through powerhouse turbines. Although as many as 11 alternative sites have been identified for single pool dams since January 1979, the study manager has indicated that only six single pool alignments are being considered at this time (Fig. 1). Pool size for these alternatives ranges from roughly 3,600 acres (Wilson) to over 24,000 acres (Dudley-Treat-Lubec). Estimated installed capacity for the single pool plans would be anywhere from less than 100 to roughly 450 MW.

In addition to the single pool plans, two-pool systems have also been considered. These involve both a high pool/low pool layout and a linked basin concept. Both systems would result in a longer generating time than is possible with single-pool design. However, multi-pool plans were found to be less cost effective than the selected single pool alternatives, and have consequently been dropped by NED from further consideration.

Electric power would be the major benefit from the tidal power project. However, benefits are also expected from recreation, fisheries-mariculture and area redevelopment. Power generated at the project would be integrated into the New England Power Pool (NEPOOL). New transmission lines would be built to convey power from the project to as far as the Bangor, Maine area; depending upon ultimate power output. The Bonneville Power Administration (BPA) would be responsible for planning and building transmission facilities.

II. Environmental Aspects of the Project

A. Introduction

In planning aid letters to NED, dated February 23, 1978 and July 18, 1978, the FWS indicated that numerous environmental studies would probably need to be conducted before an accurate assessment of environmental impact could be made. In response to our recommendations NED helped fund the FWS's Maine Coast Ecological Characterization, an ongoing study that is describing the coastal ecosystem in Maine. Scheduled for completion in Spring 1980, the Characterization should provide an improved ecological picture of the Maine Coast, thus permitting a better understanding of potential impacts of the tidal power project in Cobscook Bay.

In addition to having a somewhat incomplete knowledge of the marine ecosystem in Cobscook Bay, we do not have the detailed project plans ordinarily available in making impact assessments. Therefore, our evaluation of the project will be generic, and for the most part applicable to all of the alternative dam alignments that have been identified by NED. We have reviewed available literature on biological impacts of tidal power, and will apply this knowledge to what is known regarding the ecology of Cobscook Bay.

B. Marine and Estuarine Habitat

1. Resource Evaluation

Cobscook Bay is located in southeastern Washington County, Maine in the Passamaquoddy region of the Gulf of Maine. Resembling an oak leaf in its shape, Cobscook is 38 square miles in area, and it has a shoreline length of roughly 233 miles. Numerous embayments, coves, islands and peninsulas are located throughout the Bay. Depths exceed 150 feet in several locations, but generally are much less (NOS Navigational Chart 801).

Extreme tidal range is perhaps the most significant oceanographic characteristic of Cobscook Bay. Tides vary from 11.3 to 25.7 feet (mean 18.1 feet) depending upon the stage of the lunar cycle (CE 1978). Tidal currents carry cold, Gulf of Maine water, well-supplied with nutrients, to all portions of the Bay. The high tidal range results in substantial intertidal area in Cobscook Bay. Roughly 37% (9,000 acres) of the area behind the proposed Dudley-Treat-Lubec dam is intertidal, most of which is mudflat (Table 1). Lesser amounts of rocky shore, aquatic vegetation beds (primarily eelgrass) and emergent saltmarshes also exist throughout the Bay.

Water temperature ranges seasonally from about 1 to 13°C; salinity throughout the Bay varies from 31 to 33 $^{o}/oo$ (Trites 1961). Dilution of Bay waters by freshwater inflow is minimal. Consequently, Cobscook remains relatively ice-free during winter.

A diverse, and in some cases abundant fauna exists in and around Cobscook Bay. Production by phytoplankton (principally diatoms) is believed to be higher here than elsewhere along the Maine Coast (pers. comm. Peter Larsen 1979). Of even greater significance to the trophic ecology of the area is production by macroalgae (seaweeds) and eelgrass. Zooplankton abundance is reportedly greater in Cobscook Bay than in other parts of the Quoddy Region (Legare' and Maclellan 1960). Copepods are by far the most common zooplankton in the Bay; however, euphausiids and chaetognaths are occasionally seasonally abundant.

Species diversity of benthic invertebrates is higher in Cobscook Bay than anywhere else along the Maine Coast (with the possible exception of the Sheepscot estuary). Some of the invertebrates found in the Bay are found only in deeper waters of the Gulf of Maine, or are arctic species that occur in few other places in the continental U.S. The Maine State Planning Office has designated three Critical Areas in Cobscook Bay because of unique occurrences of invertebrates.

The vast intertidal and subtidal areas in the Bay support commercially harvested intervertebrates, of which soft-shell clams and sea scallops are the most important. Soft-shell clams are Washington County's principal commercial species, and County landings are higher than elsewhere in Maine. Cobscook Bay's enormous intertidal flats support harvestable populations of clams; however, in some areas tidal scouring and flocculent sediments limit production. Epibenthic algae is extensive in certain areas, and its smothering effect also limits clam production. In addition, access to clam areas by road is somewhat limited, making it difficult for clam diggers to reach the flats. Nevertheless, the soft-shell clam industry is the major commercial fishery in Cobscook Bay.

Sea scallops are found in the deeper portions of Cobscook Bay. Important scallop areas include Whiting Bay, South Bay/Cobscook Bay, and Johnson Bay/Friar Roads (Maine State Planning Office 1977). A small number of fishermen drag for scallops each spring.

Marine worms (sandworms and bloodworms) are also harvested from the intertidal flats in Cobscook Bay. However, worm populations are not well suited to the compact sediments that occur in Cobscook (pers. comm. M. Richards 1979). Mudflats outside the Quoddy Region are softer and support denser worm populations. Nevertheless, some worms are harvested in Cobscook Bay.

Lobsters are also found in Cobscook Bay, although not in sufficient numbers to support a significant commercial fishery. A large percentage of lobsters that are caught in this area are reported to be larger than those caught along other areas of the Maine Coast. Reasons for low levels of production by lobsters in the Cobscook area are not well known, but could relate to numerous factors, such as tidal scour, turbulence, siltation, poor food supply, predation or poor larval survival. Also involved may be the fact that extreme tidal range exposes for extended periods the rocky areas where lobsters would normally be found (Dow 1959).

Other commercially exploited species of invertebrates found in the Cobscook area include blue mussel, periwinkle and rock crab. These species have historically been underutilized commercially due to poor market demand. Currently, a small-scale mussel aquaculture project is underway in Cobscook Bay (scallop and oyster culture are also being studied by the same enterprise). Periwinkles found in the Bay reportedly grow well and to large sizes, thereby offering potential commercial utilization should market conditions improve. At the present time a limited year-round fishery exists for periwinkles in the Bay.

Commercial fisheries for herring and other finfish are insignificant inside Cobscook Bay compared to those for clams and scallops. Although herring have historically been caught inside Cobscook Bay, most fishing effort takes place outside the Bay, specifically on the Perry shore of Western Passage. The town of Eastport remains an active center for herring processing. One packing and three processing plants receive herring landings (mostly from Canada).

Virtually no groundfish are commercially exploited inside Cobscook Bay. There are small fisheries for alewives and eels in the Dennys and Pennamaquan rivers, however (see page 12).

An unquantified amount of recreational fishing takes place in Cobscook Bay. Principal finfish species taken include winter flounder, mackerel, redfish, cod, pollock, tomcod and striped bass (an occasional visitor to the Dennys River). Atlantic salmon and sea-run brook trout occur in some of the Bay's tributaries (see page 11).

The Eastport area is the only location where redfish can be angled from shore. This species is abundant in deeper waters of the North Atlantic and is normally found at depths of 40 to 200 fathoms in the Gulf of Maine. At Eastport redfish are commonly observed at the surface, feeding on euphausiids. The National Marine Fisheries Service reports this surface occurrence of redfish as unique throughout the species' range, and the agency has proposed Eastport Harbor be designated a sanctuary under the Marine Sanctuaries Act (16 U.S.C. 1431-1434).

The value of Cobscook Bay as a spawning and nursery area for fish is uncertain. The plankton surveys of Legare' and Maclellan (1960) in the inner Quoddy region contained fish larvae of numerous species but never in large concentrations. Species found frequently included rock eel, sand dab, lumpfish, wrymouth and sea snail. Commercially and recreationally important species that were found less frequently included cod, haddock, whiting, smelt, pollock, butterfish, winter flounder, hake and herring.

Marine mammals, including harbor porpoises, seals and whales are commonly observed in the Quoddy region. Inside Cobscook Bay harbor seals are probably the most abundant marine mammal, although porpoises and whales are occasionally observed there, also. Whether there are any seal breeding sites inside Cobscook is not certain, although pups have been observed in the Bay.

Cobscook Bay's intertidal areas attract what is reported to be the highest density of shore and wading birds in the State (FWS in press). Species that frequently congregate in the area include semipalmated sandpiper, Bonaparte's gull, herring gull, great blackbacked gull, ring-billed gull, sanderling, black-bellied plover, semipalmated plover, least sandpiper and dowitcher. Cobscook Bay (and Bay of Fundy in general) serves as a shorebird staging area where they feed and accumulate energy reserves needed in their long uninterrupted flight to wintering areas primarily in South America (Morrison 1977). Great blue herons are also commonly observed in the area; however, it is not certain whether there are active rookeries on the Bay.

Cobscook Bay is also an important wintering area for waterfowl. According to Maine Inland Fisheries and Wildlife data, the Cobscook area is the only management unit in Maine where numbers of black ducks are not declining. Other abundant waterfowl species that winter in the Bay include bufflehead, oldsquaw, scoters (white-winged, black, and surf) and red-breasted merganser. Lack of extensive ice-cover makes Cobscook an attractive wintering area for these ducks.

Terrestrial birds of prey that utilize the marine resources of Cobscook Bay include the bald eagle and osprey. Both depend heavily on fish species such as alewives and eels for food, although eagles feed more on waterfowl in winter. (More will be said on eagles on page 13.) Inasmuch as Cobscook Bay attracts numerous shorebirds, their predators (e.g., merlin) are also found around the Bay.

2. Impact Assessment

a. Physical and chemical changes

The immediate impact of placing a dam in Cobscook Bay will be to alter existing tidal and circulation regimes. These effects will be evident on the seaward side of dam as well as within the impoundment. Mean tidal range behind the dam will be reduced from 18 feet to roughly 12 feet (CE 1979), with mean sea level increasing by roughly 3 feet. Although high tide will remain at about +9 feet msl, low tide will be elevated to roughly -3 feet msl. Seaward of the dam tidal amplitude would probably increase, and general circulation patterns within the inner Quoddy region would be altered to some degree, based on Gordon and Longhurst's (1979) evaluation of potential tidal power development in the upper Bay of Fundy.

Circulation between Cobscook Bay and the Gulf of Maine will be reduced resulting in decreased velocities and diminished vertical mixing within the Bay. Seasonal thermal stratification may also occur, causing greater variation in surface water temperatures. Decreased flow from the Gulf of Maine may also result in decreased salinity inside Cobscook. These modifications in existing temperature and salinity patterns will probably increase ice formation in the Bay as well as affecting existing biological communities. Altered water temperature and increased ice formation may also affect the micro-climate of the immediate region, which would also have an impact on the biota.

Flushing patterns would be substantially altered by damming Cobscook Bay. This will cause modifications in sediment transport and cycling of nutrients. Stratification of the water column could increase retention of nutrients in the deeper layers of the Bay, as well as increasing sedimentation.

An increase in mean sea level in Cobscook Bay behind the dam may affect groundwater levels and hydrologic conditions of rivers entering the Bay. Furthermore, riverine tidal regimes would be modified, having implications for the existing aquatic ecology in the river estuaries.

Shoreline habitat will be altered by changes in tidal regime, currents and wave energy. An increase in mean sea level will result in a reduction of existing mudflats. Decreased circulation is expected to alter existing sediment types in Cobscook Bay. Inasmuch as benthic communities are adapted to the scouring and sediment types now present in the Bay, modification of sediment conditions will have ecological implications. Alterations in intertidal sediments and associated fauna will have consequences for the avifauna that feed in these areas, as well.

b. Primary production

Production by phytoplankton will be affected due to the project's impact on circulation, water temperature, nutrient distribution and possibly light penetration (through decreased suspended sediment load). Production by epibenthic algae, saltmarsh plants and subtidal vegetation (macroalgae and eelgrass) are also likely to be impacted. Net primary production will undoubtedly be changed. However, the extent of this change and the significance of alteration in individual components of primary producers are not known and would require further study. This analysis would need to be applied to each of the alternative impoundments to determine which alignment would have the least effect on primary production.

c. Zooplankton

Impacts upon existing phytoplankton and distribution of detritus will in turn affect development of zooplankton populations inside Cobscook Bay. Legare' and Maclellan (1960) speculated that impacts of the Passamaquoddy Tidal Power Project on zooplankton would be insignificant, considering the fact that the major endemic copepods in the area are tolerant of a wide range of temperature and salinity. However, they pointed out that the more sensitive organisms and early life stages would be most affected. This could be true for those invertebrates found in Cobscook that are more arctic in their temperature preference. Changes in abundance and distribution of zooplankton will affect other components of marine food webs in Cobscook Bay.

d. Other invertebrates

The permanent flooding of substantial areas of mudflats will result in immediate mortality for those invertebrates adapted to an intertidal existence (e.g., soft-shell clams). Alterations in sediment type, compactness and siltation rate will affect the redistribution and abundance of existing fauna. Changes in food supply and water temperature will affect physiological processes such as growth and reproduction.

A sound understanding of present temporal and spatial distribution of invertebrate populations will be necessary to predict impacts of the tidal power project on these and associated species. Current knowledge is somewhat limited due to lack of extensive population sampling. However, certain critical invertebrate areas have been identified (Birch Islands, Crow Neck, Wilburs Neck) by the Maine State Planning Office. These locations contain unique intertidal populations of invertebrates, that are either arctic forms rarely found on the U.S. coast, or are subtidal animals rarely found in the intertidal zone. All of the proposed major impoundments would impact these critical invertebrate areas (with the exception of the Wilson alignment).

Potential impacts of tidal power development on commercially valuable marine invertebrates were discussed in earlier reports on tidal power (Dow 1959, Wilder 1960, Medcof 1962). Although we are not especially concerned with project impacts on the commercial fishing industry, we would expect subsequent environmental investigations to study the effects of the project on invertebrate populations in general, be they commercially valuable or not.

e. Finfish

Project-induced changes in abundance and distribution of invertebrates will have indirect effects on other elements of marine food webs, including both predator and prey populations. Fish populations in Cobscook Bay will be affected by the project. Generally, placing a dam in the Bay will interrupt established migratory routes and modify distribution and abundance of food. Changes in temperature and salinity may affect physiological processes such as growth and maturation. However, in order to accurately evaluate impacts on fish we would need to know more about anticipated oceanographic conditions within the impoundment. More information would be necessary also on distribution, abundance and life history requirements of fish species within the Bay throughout the year. Finally, we must know more about the individual dams (specific location, design, operational characteristics). Until these kinds of information become available we cannot be certain of potential impacts on fish.

Impacts of tidal power on commercially important marine finfish were discussed by Dow (1959), Kerswell (1960) and McKenzie and Tibbo (1961). As with commercial invertebrates we are not as concerned with the project's impact on commercial finfish as we are with potential changes in fish populations in general.

f. Avifauna

Permanent flooding of existing intertidal habitat would also impact feeding areas for shore and wading birds. Principal shorebird areas in Cobscook Bay are located on Moose Island (Carryingplace Cove, Half Moon Cove) and generally in outer portions of the Bay (pers. comm. N. Famous). Consequently, potential tidal power dams that would exclude these outer areas would have less impact on feeding areas than would those dam alignments impounding all of Cobscook Bay. Project-induced changes in tidal currents, sedimentation patterns, salinity and ice cover could have a substantial impact on food supply (Morrison 1977).

Inasmuch as mean high water will remain unchanged, high-tide roosting areas for shorebirds should not be inundated by the project. However, construction of project structures (dams, access roads, etc.) may impact important roosts.

Waterfowl populations accustomed to wintering in Cobscook Bay would be impacted by potential changes in ice cover and food availability. Furthermore, project structures may improve access to hunting areas.

Important waterfowl areas inside Cobscook Bay would be affected by each of the proposed dam alignments. Sea ducks (scoters and eiders) commonly raft in South Bay, East Bay, Straight Bay and Johnson Bay. Inner portions of Cobscook are especially important for black ducks, teal, bufflehead and goldeneyes. Oldsquaw and mergansers can be found in the vicinity of Falls Island.

In addition to impacting shorebirds and waterfowl that use Cobscook Bay the project could affect seabirds. However, other parts of the Quoddy Region are generally more important for seabirds than is Cobscook Bay. Therefore, the magnitude of seabird impacts is uncertain.

Predatory raptors could also be affected by alterations in marine and estuarine conditions. Both the bald eagle (see page 13) and osprey rely heavily on fish from Cobscook Bay. The merlin on the other hand feeds primarily on shorebirds, and would be impacted by a decrease in availability of prey.

g. Marine mammals

The project would also affect harbor seals, the most abundant marine mammal in Cobscook Bay. Feeding habits and perhaps reproduction would be affected by placing a dam in Cobscook Bay. The existence and location of pupping areas is uncertain at this time. Consequently, little can be said about impacts of individual dam alignments on seal reproduction. Similarly, little is known about local food habits of seals; and until such information becomes available, it would be difficult to speculate on impacts on food availability.

Other marine mammals occasionally reported for Cobscook Bay include harbor porpoises and whales. However, these animals are more common in other areas of the Quoddy Region. Consequently, impacts of the project on these animals are not known.

C. Terrestrial Habitat

1. Resource Evaluation

Land areas surrounding Cobscook Bay consist of rocky, hilly terrain and contain numerous streams, lakes and bogs. Most of the land cover around the Bay is made up of softwood or mixed hardwood-softwood forest. Agricultural fields and blueberry barrens also exist around Cobscook but in relatively lesser amounts.

Major softwoods found in the area include spruce and fir. Pine, hemlock, cedar and tamarack also are found to a lesser extent around the Bay. Hardwoods growing near Cobscook include birch, aspen, maple and beech. Alders border the streams, bogs and lakes in the area. Most of the forest cover is second growth timber, with virtually all of the virgin forest having been logged or destroyed by fire.

Human activity around Cobscook Bay is relatively minor. Agricultural development is somewhat concentrated along the eastern shores of Leighton Neck and Seward Neck, and along Maine Route 189 in Lubec. Elsewhere farmland is sparsely scattered around the Bay. Timber harvesting does occur but not on a large scale as in other parts of Maine further inland. Urban areas are small with Eastport being the most populated town (2,029 in 1976).

Nearly all types of wildlife habitat found in Maine exist around Cobscook Bay. This fact together with relatively low levels of human activity result in the presence of a rich and diverse wildlife fauna.

Upland big game species found around Cobscook Bay are white-tailed deer, moose and black bear. Smaller mammals commonly found in the area include bobcat, snowshoe hare, red fox, red squirrel, porcupine, muskrat, beaver, raccoon, and meadow vole.

Cobscook Bay and its surrounding land area support numerous species of birds. Upland areas contain excellent habitat for game birds such as woodcock and grouse, and support a variety of songbirds and predatory hawks and owls. (A total of 207 species of birds have been identified over the years at the neighboring Moosehorn National Wildlife Refuge.) Waterfowl utilize the inland as well as the coastal waters, and species such as black duck, ring-necked duck, teal, wood duck, goldeneye, bufflehead, scoters, mergansers and Canada geese are commonly observed in the area.

2. Impact Assessment

Project-induced impacts on terrestrial habitat will for the most part be those associated with the construction and maintenance of transmission lines. Unfortunately, BPA has yet to designate actual power line routes, thereby making our comments on impacts somewhat premature. However, for the purpose of making a generic assessment of transmission line impacts we can refer NED to the Maine Department of Inland Fisheries and Wildlife (1975) working paper on power line right-of-way and wildlife management (Attachment A). The MDIFW recognizes four areas in Maine that require special consideration in transmission line routing. These include:

1) deer wintering areas
2) wetlands
3) streams, brooks, rivers and other bodies of water
4) habitats supporting unique, threatened or endangered biota

Suffice it to say that each of the above situations would be encountered in the general study area identified by BPA (roughly an area 100 miles long and 50 miles wide between Cobscook Bay and the Bangor area).

Additional terrestrial habitat modifications may also take place due to altered hydrologic conditions and changes in micro-climate which may result from damming Cobscook Bay. However, the extent of these terrestrial impacts would be difficult to predict at this time. Similarly, actual construction activities (dam building, quarrying, road building, etc.) will impact terrestrial habitat. But lack of project details prevents us from speculating on the extent of these construction impacts.

D. Freshwater Habitat

1. Resource Evaluation

Although the transmission line corridor would affect freshwater habitat in various places throughout eastern coastal Maine, we will restrict our discussion of freshwater resources primarily to the coastal streams flowing into Cobscook Bay and to the diadromous fishery resources in these waters. Total drainage area for Cobscook Bay is roughly 334 sq. miles. Major subbasins include those of the Dennys River (130 sq. miles), Pennamaquan River (45 sq. miles) and Orange River (35 sq. miles). Freshwater inflow to Cobscook is relatively minor as evidenced by the cold, saline bay waters and relatively ice-free conditions in winter. Water quality in the coastal streams entering Cobscook Bay is generally high. Natural fertility is low, however, as is true with other soft-water coastal streams in eastern Maine (Taylor 1973).

Anadromous fish species found in coastal streams flowing into Cobscook Bay include Atlantic salmon, alewife, rainbow smelt, striped bass, and sea-run brook trout. American eels, a catadromous species, are also present in these streams, where they grow to maturity before migrating to spawn in the ocean.

The Dennys River is the most important Atlantic salmon river in the Cobscook drainage basin. Just one of six rivers in the U.S. that contains a self-sustaining population of Atlantics, the Dennys supports an annual run of up to 700 fish. Roughly 20 to 80 salmon are caught by anglers each year in the river (pers. comm. R. Jordan 1979).

Waterflow in the Dennys River influences the ascent of salmon from Dennys Bay. During years of normal runoff salmon begin to move into the river during late spring and early summer. However, in dry years, low flows can delay the run until fall, until which time salmon will remain in Dennys Bay. This condition can be expected roughly once every 10 years (pers. comm. A. Meister 1979).

Six other river drainages in eastern Maine contain runs of Atlantic salmon. Four of these are located in Washington County and support self-sustaining populations of Atlantics (East Machias, Machias, Pleasant, Narraguagus). The two remaining rivers (Union and Penobscot) contain runs that are maintained by stocking.

Alewives ascend the Dennys and Pennamaquan rivers to spawn in the spring. Although the Orange River basin contains excellent spawning habitat, an old dam at head of tide in Whiting prevents upstream passage of fish. Alewife runs in the Dennys are fished commercially by the towns of Dennysville and Meddybemps. Fishways on Meddybemps Lake and Cathance Lake allow passage of adult fish into lake spawning areas. Dams on the Pennamaquan are also equipped with fish ladders, allowing fish passage and commercial harvest of alewives by the town of Pembroke.

Eels are fished commercially using weirs and eel pots in the Dennys and Pennamaquan rivers. The fishery is directed toward adult eels moving downstream in late summer and fall enroute to their ocean migration. Although a fishery for immature eels (elvers) was attempted in recent years in these rivers, the foreign market for young eels has now diminished and fishermen concentrate their efforts on adult fish, still in high demand overseas.

Anadromous rainbow smelt are fished by sportsmen in the Dennys River where they are dipped in late April and early May. No winter ice fishery exists in the Dennys estuary due to the huge tidal fluctuation and uncertain ice conditions.

Striped bass are occasionally caught by anglers in the Dennys River, although few have been taken in recent years. Sea-run brook trout are found in several of Cobscook's tributaries, primarily the Orange and Pennamaquan rivers, and in East Stream in Trescott. The Dennys River, although containing a few sea-run trout, supports an excellent non-anadromous brook trout population upstream from the estuary.

2. Impact Assessment

Diadromous fish species that would be affected by the tidal power project include Atlantic salmon, alewife, rainbow smelt, brook trout (sea-run populations), striped bass and American eel. Both upstream and downstream passage of these species would be impeded by dams in Cobscook Bay. All of the proposed alignments would require fish passage facilities.

As Bell and Clay (1960) indicated, anadromous fish would probably be attracted primarily to the discharge at the powerhouse. Filling gates should not attract fish unless substantial water leaks through them when they are closed. Passage of fish through open filling gates would probably be accidental. Downstream passage of fish would probably take place primarily at the powerhouse.

A conventional fishway should accommodate upstream migrating fish with the exception of smelt and striped bass. These species would require some kind of fish lock or elevator to pass them over the dam, as they will not use a fishway.

Downstream passage of fish would also have to be ensured at the powerhouse either by using a diversion conduit equipped with some kind of attracting or screening device, or by periodically interrupting operation of the plant to allow fish passage over the spillway. However, should the tidal power generators be fitted with large, slow-rotating turbines, as was proposed during earlier tidal power studies, downstream migrants may be able to directly negotiate the turbines without significant harm. A decision on downstream passage facilities will have to be made after more definitive operational data are available.

The cost of fish passage facilities would depend upon whether a conventional fishway or a fish elevator was to be used. In terms of relative cost a fish elevator would be more expensive and would require full-time personnel for its operation in addition to higher maintenance costs. Conventional passage facilities would not have to be manned full-time and would require less upkeep.

In addition to differences in cost and maintenance, an elevator would pass more species than would a conventional fishway. Although only diadromous species have been considered with regard to fish passage requirements, a fish elevator might also be able to better accommodate some marine species affected by the dam. Further speculation on this aspect of fish passage would be premature in the absence of more definitive data on dam location, affected fish populations, etc.

E. Rare, Threatened or Endangered Species

1. Resource Evaluation

a. Bald eagle (Haliaeetus leucocephalus)

Cobscook Bay is the most important nesting area for the endangered bald eagle in Maine. In fact, roughly 20 to 25% of the total production of eagles in the northeastern U.S. takes place around the Bay. In 1978 there were 17 intact nests in Cobscook Bay; eight were occupied, and four produced young. This production rate is unrivaled anywhere else in the northeast U.S. The only other area in northeastern North America that has as healthy a population of bald eagles as in Cobscook is Cape Breton Island, Nova Scotia. Everywhere else production by eagles is believed to be below maintenance level. Whereas the bald eagle is a federally listed endangered species, Cobscook Bay is considered virtually certain to be designated critical habitat in the future. The most essential nesting and spring/summer feeding area for eagles includes all of Cobscook Bay except for the region outside Seward Neck/Birch Point (Fig. 2). However, in winter all of Cobscook Bay is significant, including the outer areas (Fig. 3).

Eagles nesting in the Cobscook area also tend to remain there through winter. Open ice-free water attracts numerous waterfowl to Cobscook in winter, providing an important element of the eagle's diet.

b. Arctic peregrine falcon (Falco peregrinus tundrius)

The endangered peregrine falcon occurs as a transient around Cobscook Bay during spring and fall migrations. However, there are no major migration corridors or concentrations of peregrines in this area (FWS 1979).

c. Shortnose sturgeon (Acipenser brevirostrum)

The shortnose sturgeon is an endangered species that is anadromous in some Gulf of Maine tributaries. However, its preferred habitat is large rivers, and its occurrence in any of the small tributaries to Cobscook Bay is unlikely. However, it does occur in the St. John River in New Brunswick, and possibly is an occasional migrant into the inner Quoddy Region.

d. Marine mammals.

Several species of endangered marine mammals regularly occur in the Quoddy Region. However, these species are under the purview of National Marine Fisheries Service and will not be discussed in this report.

e. Flora

There are no federally listed endangered plant species in Cobscook Bay. However, a species that appears on the Smithsonian Institution's Endangered and Threatened Plants of the United States is the monkey-flower (Mimulus ringens var. colpophilus). This plant occurs in river estuaries and has been reported in Machias Bay (pers. comm. N. Famous 1979). Intensive surveys in Cobscook may reveal this species.

Additional species of plants that are considered critical in Maine include three arctic species whose southernmost range is the northeast coast of Maine. These are bird's eye primrose (Primula laurentiana), beachhead iris (Iris hookeri) and roseroot (Sedum rosea). These plants are known to exist on rock outcrops in the Lubec area and north of Eastport (EPA 1978). Further surveys may reveal additional occurrences of these species inside Cobscook Bay.

2. Impact Assessment

The endangered species that would be most affected by project-induced changes in Cobscook Bay is the bald eagle. Both the peregrine falcon and shortnose sturgeon are at most only occasional visitors to the Bay. Although further surveys may prove otherwise, it now appears that the project would not affect rare or threatened plant species.

A Biological Assessment will need to be prepared by the Corps to evaluate impacts of the project on eagles in accordance with the 1973 Endangered Species Act, Section 7, paragraph C as amended on November 10, 1978. In a letter dated March 12, 1979 (Attachment B), the FWS informed NED that the Assessment would need to address potential development that might be stimulated by the project, and potential alterations in availability of food for eagles (primarily fish and waterfowl).

Because of the regional importance of Cobscook Bay for bald eagles, the FWS will be extremely concerned about potential impacts associated with the project. However, the FWS cannot offer its Biological Opinion on project impacts on eagles until the Biological Assessment has been written and more details are known about the project.

III. FWS Concerns About Tidal Power in Cobscook Bay

A tidal power project in Cobscook Bay would affect what we and many others consider to be a unique marine ecosystem. The unusual oceanographic conditions and lack of human disturbance have resulted in favorable habitat conditions for numerous fish and wildlife resources.

The FWS is extremely concerned about potential impacts of the project on fish and wildlife, especially endangered species (bald eagles), anadromous fish (Atlantic salmon) and migratory birds (shorebirds and waterfowl). Unfortunately, the survey investigation did not progress long enough to generate sufficient project data which would allow us to adequately assess project impacts on these resources, or to develop means and measures, if possible, to mitigate, eliminate or compensate for such impacts. If NED resumes the tidal power investigation, we would expect adequate environmental studies be conducted to evaluate impacts on fish and wildlife and their habitat. However, based on the information developed thus far and on our intuitive judgment, our most probable position would be to recommend against authorization of a large-scale tidal power project in Cobscook Bay.

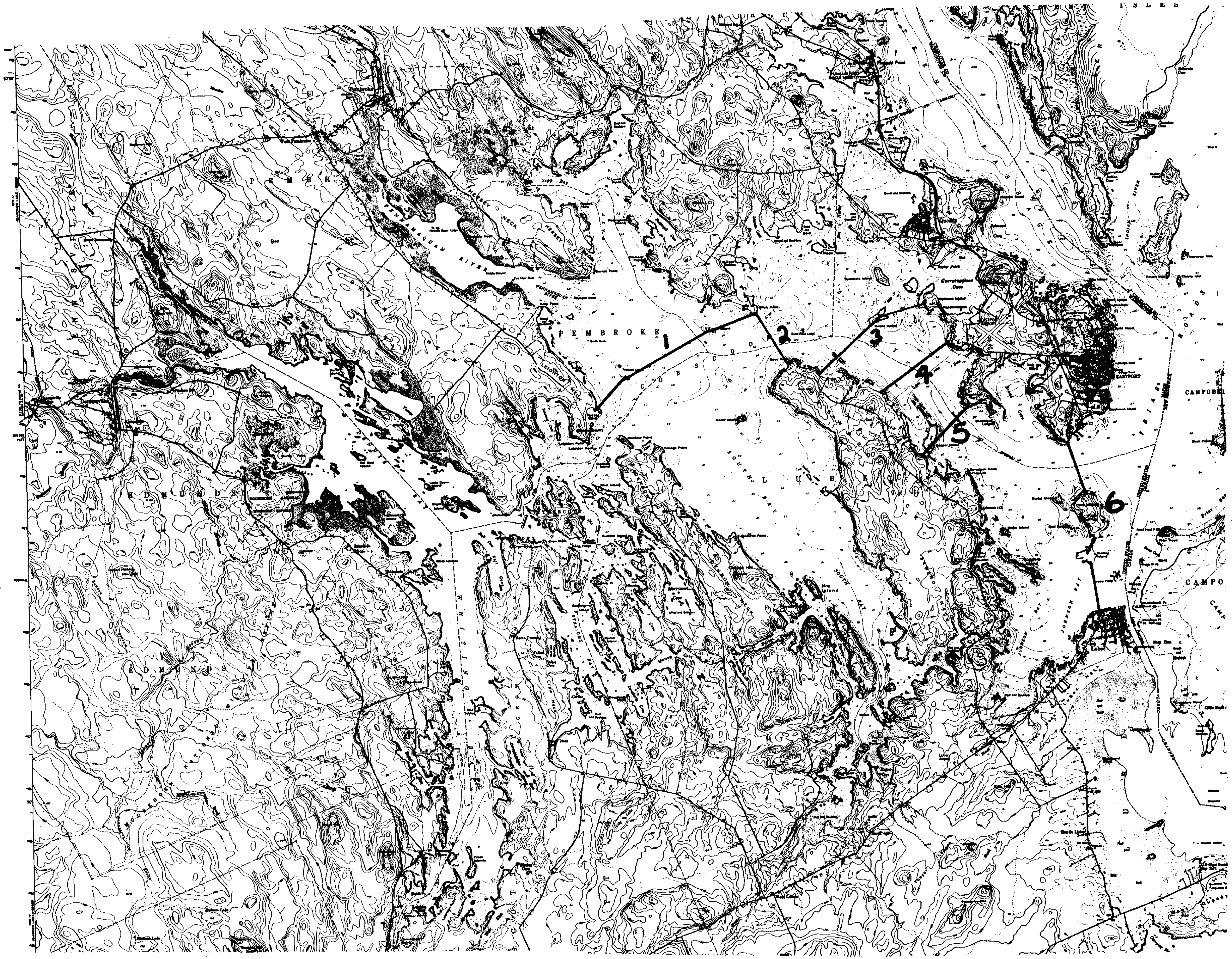
We appreciate the opportunity to review your proposal to produce tidal power in Cobscook Bay, Maine.

Table 1. Intertidal habitat affected by proposed tidal power dams.

Dam Alignment	Intertidal Habitat[1]					
	Mudflat	Rocky Shore	Aquatic Bed	Marsh	Beach or Bar	Total
Wilson	829[2]	150	218	87	89	1,373
Birch	4,144	1,278	961	553	153	7,089
Goose	4,719	1,472	1,249	592	210	8,242
Cable	4,731	1,491	1,249	603	252	8,326
Cooper	4,750	1,503	1,253	605	278	8,389
Dudley-Treat-Lubec	4,990	1,610	1,382	605	370	8,957

[1] Source of data: FWS National Wetland Inventory Draft Maps

[2] Acres



1. Wilson
2. Birch
3. Goose
4. Cable
5. Cooper
6. Dudley-Treat-Lubec

Figure 1. Alternative dam alignments as of August 1979.

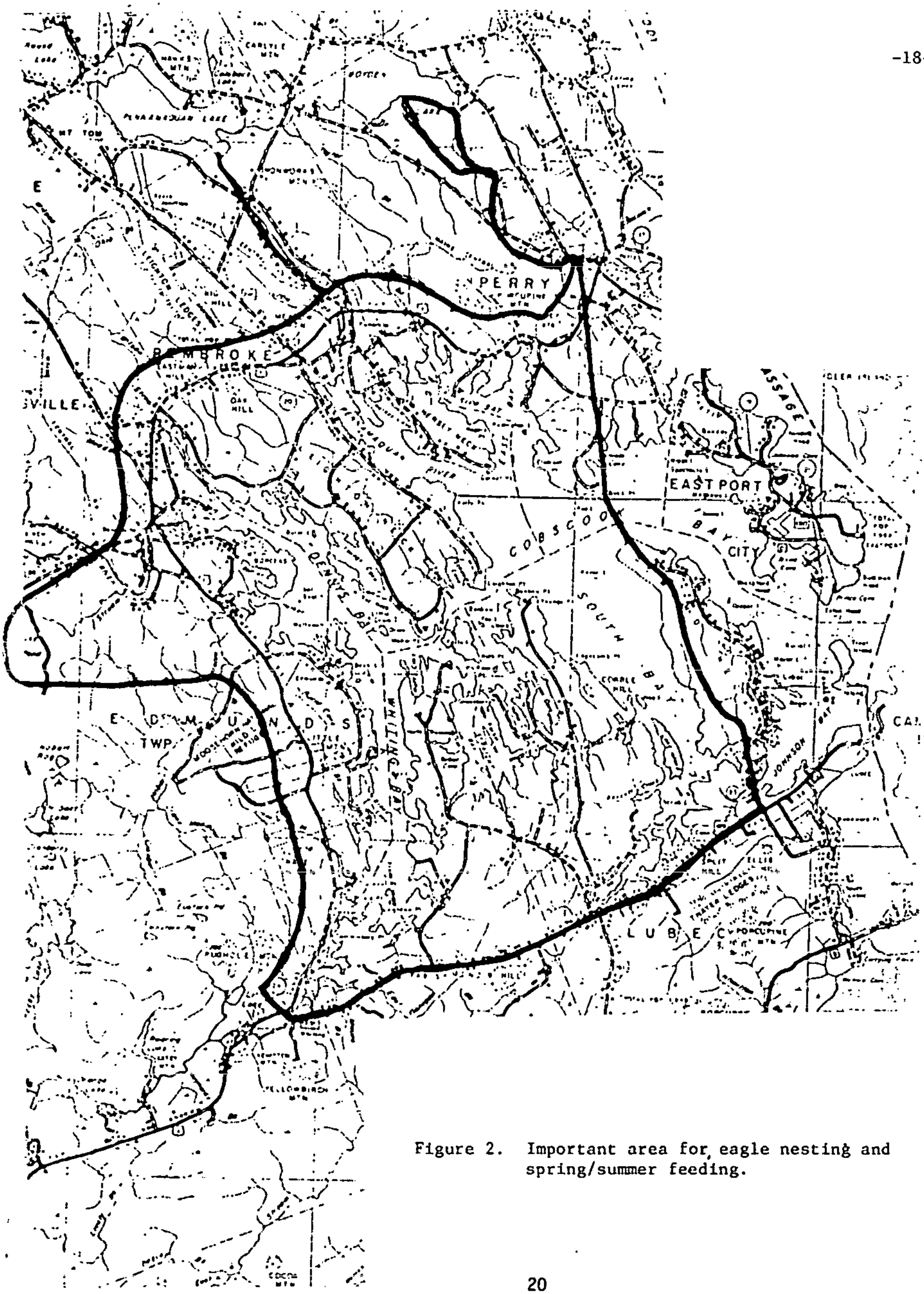


Figure 2. Important area for eagle nesting and spring/summer feeding.

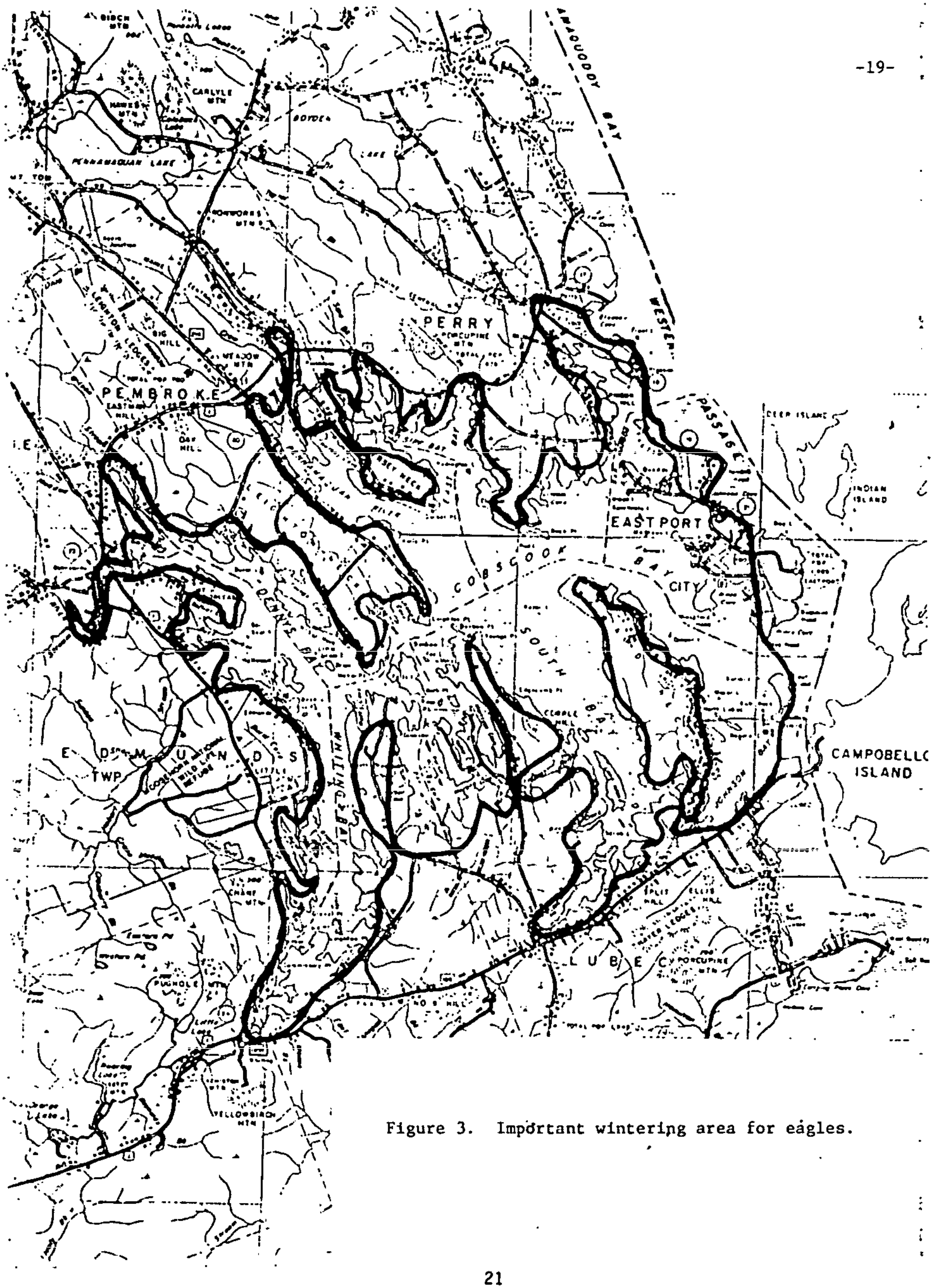


Figure 3. Important wintering area for eagles.

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Power Lines Right of Ways, and Wildlife Management - A Working Paper Prepared by the Maine Department of Inland Fisheries and Game

According to the latest Forest Service figures, approximately 90% of Maine is forested. The abundance and diversity of wildlife species found in an area are directly related to the availability of food and cover and their interspersion within the area. Generally speaking, food producing plants are associated with early successional stages; examples, reverting fields and young sapling forests and shelter is associated with more advanced successional stages. Maintenance or creation of good wildlife habitat depends on alterations of vegetative types. This change can be accomplished by timber harvests, mowing, controlled burning, or herbicide application. Therefore, in forested areas., power line rights of way provide an early successional stage which improves habitat conditions for most wildlife species. Through relatively open areas, the right of way presents a potential for management for a vegetative stage of value as food and cover to some species. With few exceptions, rights of way are beneficial to wildlife.

In Maine, four specific areas that require special management considerations can be defined; these are:

1. Deer wintering areas
2. Wetlands
3. Streams, brooks, rivers, and other bodies of water
4. Habitats supporting unique, threatened or endangered wildlife

Deer Wintering Areas

During the winter months, deer concentrate in areas where topography and/or forest cover type provide protection from chilling winds and deep snows. Normally, in northern Maine, deer wintering areas consist of spruce and fir in the 35 to 64 foot class with a canopy density of 70 percent or better. In the southern portions of the state, a variety of softwood types, such as hemlock and white pine are utilized for cover. The Department supports timber harvesting in these shelter areas as a means of providing continuous cover but does not support extensive cuttings or permanent openings which would reduce or destroy the value of the shelter.

Cutting and maintenance of a brush successional stage adjacent to these shelter areas are valuable as they provide winter food. The impact created by a power line right of way will be dependent on the size and configuration of the softwood cover and the alignment of the proposed line. As an example, a long narrow wintering area following a stream may be greatly damaged by a power line following the axis of the area; but a line running parallel to the same shelter area may cause little or no damage or be entirely beneficial depending on the species of wood cut and the slope of the land.

The effect a particular right of way* will have on a deer wintering area cannot be entirely covered by general guidelines. However, the following points should be considered:

* referred to as R.O.W. throughout this paper

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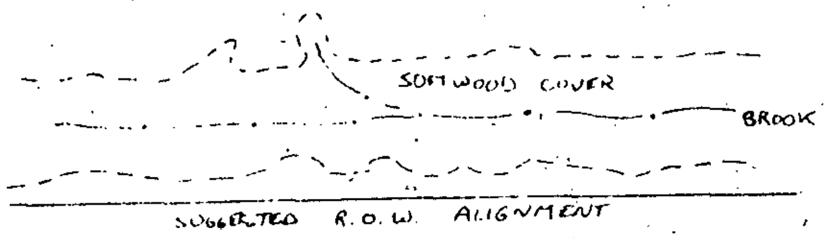
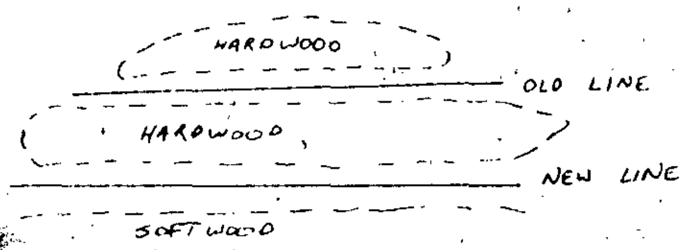
1. In deer wintering areas where R.O.W.'s will be necessary they should parallel and be outside of the shelter portion of the wintering area.



2. In areas where R.O.W.'s must cross the deer wintering area, the line should cross in such a manner that the remaining portions of the shelter area are not rendered useless and deer movement across the line is not restricted. The following methods may be used to insure continued use of the deer wintering area:

a. The width of the cleared strip should not exceed the height of the forest overstory adjacent to the right of way.
b. Trees approaching or exceeding safety standards could be removed if stand density is not affected, or topped to maintain lower level shelter. Gulleys crossing the R.O.W. at angles perpendicular to prevailing winter winds may serve as winter travel lanes. Such areas should remain in dense cover.
c. Where more than one line is necessary, towers should be used to allow multiple lines on one R.O.W. /or/ in some areas it may be possible and desirable to divide lines so an island of older growth is left between a new and existing R.O.W. Such an arrangement would reduce wind movement and create more edge. An arrangement of this type would be most beneficial if hardwoods predominated the new R.O.W.



d. By-passing deer wintering areas at great distances would be less desirable than locating a R.O.W. adjacent to a shelter area.
e. Creation of a brushy interface between the R.O.W. and the shelter area would be desirable and a selective cutting and spray program conducted on a rotation which would provide browse above the normal snow level would be beneficial.

Wetlands

Water is essential to wetlands and wetlands are critical to aquatic species and also beneficial to most terrestrial species. Wetlands vary in type ranging from coastal salt marshes to interior fresh marshes and wooded swamps. Power line R.O.W. present two problems:

1. Disruption of waterfowl behavioral patterns - experience by biologists in Wisconsin and Illinois have indicated that "power lines have an umbrella effect upon the use of waterfowl habitats by most species of ducks." It is believed that power lines result in the complete loss of use of habitat directly under the line and its effects extend as far as 1/4 of a mile beyond (Jeffrey A. Davis, Terrestrial Ecologist, N.Y. Public Service Commission in personal communication with Frank Bellrose and R.A. Hunt). Mortalities are also known to occur as the result of collisions with lines and towers. Avoidance of power lines by waterfowl may affect hunting opportunity and breeding on high value marshes. In order to prevent waterfowl losses, it is recommended that lines be placed underground especially in high use areas. On relatively small areas lines should be placed away from the wetland rather than constructed so as to pass through or over them.

2. Destruction of wetland habitat - crossing wetlands often involves filling or other alteration to provide bases for towers and poles or a roadbed for equipment constructing or maintaining the line. The use of heavy equipment as well as the physical alteration of the habitat should be discouraged whenever possible, since such operations may contribute to siltation and permanent destruction of some plant types. The impact of crossing areas underground would be less since the area could be restored to its original elevation thus allowing re-establishment of aquatic species. This method, although more costly, should be given consideration particularly on high value sites.

Rivers, Streams, Brooks, and other Bodies of Water

Rivers, brooks and streams serve as spawning and nursery areas for salmonids and smelt which provide forage for salmonids. Clean gravel and cool temperatures are required for successful spawning and survival and growth of young and adult salmon and trout. Streams and brooks supporting cold water species must be protected against; (1) siltation, which destroys spawning areas and trout habitat; (2) removal of bank vegetation, which would accelerate erosion and allow exposure to the sun; (3) destruction of springs, which maintain stream flow; and (4) obstruction of the stream, which would prevent fish migrations.

Brooks and streams also provide avenues through which herbicides, pesticides and other pollutants can be carried downstream. Most types of these chemicals are toxic to both fish, wildlife and humans.

To prevent detrimental effects associated with power line installation, no cutting should occur within the distance from the stream or brook established in the following table:

Average Slope of Land Between exposed mineral soil and normal high water mark percent	Width of Non-cut Strip (measured in feet from the brook to the closest cleared R.O.W.)
0	25
10	45
20	65
30	85
40	105
50	125
60	145
70	165

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In addition, poles and towers should be set far enough away from the banks of streams so that it will not be necessary to reset poles from time to time due to bank undercutting.

Spraying by a selective method should create few problems if an untouched buffer is allowed to remain. In the case of broadcast sprays, which is not a recommended practice, equipment should be shut off before crossing a brook or stream and under no circumstance should equipment be flushed, rinsed or washed in a body of water.

Private stream, brook and river crossings involving alterations to more than 300 feet (100 feet by public works) of stream bank (both shores combined) or any stream, brook or river crossing, including aerial crossings of transmission lines, whose supporting structures are within or abutting the banks, requires a permit from the Maine Department of Inland Fisheries and Game.

Habitats Supporting Unique, Threatened or Endangered Wildlife

Maine is fortunate in that, as yet, no resident species of wildlife have been declared to be an endangered species by either the federal or state government. Certain species are considered unique however. Bald eagle, osprey and heron nesting areas are distributed throughout the State, and because of their distribution are covered in these general guidelines. Others such as black terns, common puffins and storm petrels occupy rather limited areas and will be considered on a project by project basis. Since these species are unique, they offer great appeal to the nature enthusiast, and to many these species symbolize wilderness and provide an escape from the artificial structures of the human world. To insure the intrinsic values of such areas are maintained, nesting areas of these unique species should be avoided or screened by a natural buffer strip to maintain the natural integrity of the area.

The quality of the bald eagle, osprey and heron nesting areas may be affected by R.O.W.'s in the following manner:

1. Destruction of nesting habitat - Nests of the aforementioned species are located in older trees often in close proximity to water. In Minnesota nearly all eagle nests that have been studied are in trees over 100 years old. Those trees in which nests are located should not be cut. The U.S. Fish and Wildlife Service further recommends that three to five additional old-growth trees be reserved in the vicinity of the nest for roosting and potential future nest sites.

2. Mortality of young from human disturbance - Reduced nesting success due to nest abandonment and loss of young birds have been attributed to disturbance by aircraft or other human activities during the nesting season. The U.S. Fish and Wildlife Service recommends that no development activities such as timber cutting and road construction or other disturbing factors such as aerial spraying or low level reconnaissance flights be allowed within one-half mile of any nest during the nesting season (March through July).

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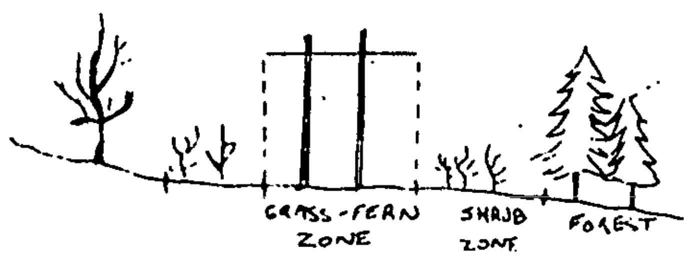
24/75

Although the preceeding recommendations apply primarily to eagles the same principles can be applied to all avians which depend on trees for nest sites.

Wildlife Enhancement

Potential exists for the enhancement of wildlife habitat on some R.O.W.'s. Lines crossing open farmland may be allowed to revert to alders and other shrub types such as hawthorn, cherry, and various viburnums. Selective cutting and spraying programs on R.O.W. should be aimed at eliminating trees and allowing the growth of grasses, forbs, herbs, and shrubs. Work in Pennsylvania indicates that a 25 year rotation on alder stands with some cutting done every 5 years provides excellent woodcock habitat. Broadcast sprays or other non-selective methods such as bulldozing should not be used as a means of vegetation control.



Initial R.O.W. clearing should be done in a manner that will protect already established valuable food producing trees and shrubs. Wire stringing areas and access roads may be mulched and seeded with grasses or legumes to prevent erosion and provide a food supply for some wildlife species. Maintaining these areas in this manner should benefit the utility company by providing a ready access system for line inspection and repair.

Appreciation is expressed to Mr. Frank Gramlich, State Supervisor, U.S. Fish and Wildlife Service, for his assistance in reviewing this paper and to personnel of Central Maine Power Company whose interest in this subject prompted its development.

M.I.F.& G.
:4/75

Attachment (B)

Colonel John P. Chandler
Division Engineer
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

MAR 12 1979

Dear Colonel Chandler:

This supplements our letter of February 12, 1979, in which we made a preliminary review of the Cobscook Bay Tidal Power Project.

My staff has since met with eagle biologists from the Maine Department of Inland Fisheries and Wildlife and the University of Maine. These biologists felt the tidal power project has the potential of affecting bald eagles. However, lack of definitive data did not allow an evaluation of the magnitude of the impacts, nor did it provide for a determination of whether the impacts in total would be negative or positive. The group also discussed what information would be needed to assess the project's potential affects on eagles.

The 1973 Endangered Species Act, Section 7, Paragraph C amended on November 10, 1978, requires that a Biological Assessment be prepared when a construction project may affect listed or proposed species or their habitat. As bald eagles inhabit the project area, an assessment of the project's impacts is required as a prerequisite to a Biological Opinion.

The following comments are offered to assist you in developing your Biological Assessment of the Cobscook Bay Tidal Power Project.

I. Development

A. What types of development will be stimulated by the power project?

1. Recreational
2. Industrial
3. Residential
4. Aquacultural

B. Where and to what extent will development occur?

C. How will this development affect bald eagles?

D. If adverse affects are anticipated, how will impacts be mitigated?

II. Food Supply

A. What are the relative sizes of each habitat type in the bay area and how will their size change after the project is operational?

B. How important to eagles is each habitat type and how are they utilized?

C. What are the stocks of currently used eagle forage species? How and to what extent will the project affect these food items?

D. If changes in the bay's species composition occur, will these species be readily available as eagle forage?

E. How will availability of eagle foods be affected by physical changes within the bay?

Please contact my office if we can be of further assistance in planning studies for your Biological Assessment.

Sincerely yours,

Regional Director

cc: David Riley (ARD-AHP)
Gordon Russell - Concord NH (ES) ✓

RBiggins/ljd

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Environmental & Technical Services
Division
Environmental Assessment Branch
7 Pleasant Street
Gloucester, Massachusetts 01930

January 4, 1980

Col. Max B. Scheider
Division Engineer
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Scheider:

Enclosed find our report identifying the probable impacts upon marine resources and marine habitats that would result from implementing a large-scale tidal power project in Cobscook Bay, Maine. This report is prepared as part of, and fulfills contractual obligations we assumed under Agreement No. 79-C-08 on the Tidal Power Project Study, Cobscook Bay, Maine.

If you have any questions concerning this report, please feel free to call upon us.

Sincerely,

Marvin F. Boussu

Marvin F. Boussu
Branch Chief

Enclosure

TIDAL POWER STUDY

COBSCOOK BAY, MAINE

Environmental Assessments and Evaluations

Prepared for
Corps of Engineers
New England Division

by

National Marine Fisheries Service
Northeast Region

January, 1980

CONTENTS

I. INTRODUCTION

The Corps of Engineers (COE) has been commissioned to study the feasibility of implementing tidal power in Cobscook Bay, Maine. The study will determine the economic feasibility of the project under present conditions, investigate environmental concerns, and explore alternatives for the purpose of recommending a specific plan to resolve future problems concerning electrical power requirements of the State of Maine and New England.

The purpose of this report is to identify probable environmental impacts that will attend implementation of a large-scale tidal power project in Cobscook Bay, and fulfills an agreement between the New England Division, Corps of Engineers, and the National Marine Fisheries Service (NMFS).

A. Tidal Power

Use of tidal power dates at least from the Eleventh Century, when small tide mills were used to grind corn. In this area, Slades Mill, a tidally-powered unit, was built in 1734 in Chelsea, Massachusetts, to grind spices. This mill developed about 50 horsepower. With the advent of inexpensive electric power, produced by fossil fuels and by hydroelectric plants, devices using tidal power became obsolete and were neglected. Today, increasing demands for electric power and rapidly escalating prices for fossil fuels make alternate methods for producing electricity more and more attractive. An ancillary benefit of utilizing alternate methods may be to reduce our dependence upon foreign supplies of oil.

Tidal power also appears to have significant ecological advantages over methods presently employed to generate electricity. The more salient among these being: the energy source is renewable and locally available;

essentially no fuel is required; few or no pollutants are produced, and there are only minor public safety hazards.

B. National Marine Fisheries Service Involvement

The NMFS agreed to assist the COE with the environmental aspects of this study. As part of this agreement, NMFS would produce environmental assessments and evaluations for the various tidal power schemes proposed, and assist in the ultimate preparation of a qualitative type environmental impact statement through a review and comment process. Because of the unanticipated early end of this feasibility study, we have been asked to prepare only a general environmental assessment statement for the most economically favorable schemes studied by the COE.

Apart from this agreement, NMFS has an independent mandate to protect living marine resources and their habitats from damage and/or destruction. We stress protection and preservation of habitats, as well as the living marine resources, because the former is the keystone for any productive marine ecosystem.

C. Project Background

Tidal hydroelectric projects in the Passamaquoddy Bay area have been studied intermittently for the past 60 years. In 1919, Dexter P. Cooper, an American, first became interested in harnessing the tides of Passamaquoddy and Cobscook Bays to generate electrical power. His first plan was a two-pool scheme, using Passamaquoddy Bay as a high pool and Cobscook Bay as a low pool. For various reasons Cooper's plans were postponed, and in 1935 the United States Government acquired the assets of Dexter P. Cooper, Inc.

In January of 1935, the American Passamaquoddy Tidal Power Commission recommended that a single-pool power project be constructed in Cobscook Bay. This project was designed so that it could be incorporated into a two-pool international plan. The COE began construction on the single-pool scheme in May of 1935 and continued until August 1936, when funding was terminated. Three dams were built during this period. One dam was built between Treat and Dudley Islands. Another dam was built between Pleasant Point and Carlow Island and the third between Carlow Island and Moose Island. The last two dams presently serve as one of two major highways to Eastport, Maine.

In 1956 an International Joint Commission (IJC) was charged with investigating the economic and engineering feasibility of harnessing the tides of Passamaquoddy and Cobscook Bays. The IJC created an Engineering Board and a Fisheries Board to study various aspects of this project, and published a series of reports on its economic, engineering, and biological studies in 1959, wherein it was recommended that further consideration be given to the scheme. However, the project did not have a favorable benefit to cost ratio. Additional studies were conducted intermittently throughout the 1960's and early 1970's, but no action was ever taken to implement the project.

The joint U.S./Canadian venture into tidal power has been abandoned and at the present time each government is considering tidal power projects completely within their respective territorial jurisdictions. Canada is studying the feasibility of using tides of the Bay of Fundy to generate electrical power, while the United States is considering a similar project for Cobscook Bay, Maine. The latter plan has been shown to have an unfavorable benefit to cost ratio under present conditions and is, temporarily at least, being held in abeyance.

II. PROJECT DESCRIPTION

The COE considered about 90 different schemes to generateelectrical power using the tides of Cobscook Bay, Maine. These included single-pool, multi-pool, and linked basin configurations. Impoundment areas of various sizes and different generating capacities (from 5 to 450 megawatts) were included in the study.

According to the Corps' analyses, the most economically favorable schemes are single-pool alternatives with large impounded areas having relatively small installed capacity.

There are two possible schemes using a single-pool: single-tide, producing power only on the ebb tide or on the flood tide; or double-tide, producing power during both the ebb tide and the flood tide.

Generally the single-pool, single-tide scheme yields the most power of any of the various schemes. Although single-pool, double-tide schemes can produce more energy and can generate over a longer period of time, construction costs are higher because of the need for reversible generating units and more emptying and/or filling gates. Single-tide schemes generating power during ebb tide are preferred over those generating on the flood tide.

When power is produced only on the ebb tide, the filling gates are closed at high tide. Once sufficient head has been created by the falling tide, the generating units begin to operate. As the water level in the basin lowers, the pressure head between the impounded pool and the ocean becomes too small to generate electrical power. At this point the operation ceases and the gates are closed. When the tide floods and the sea level has reached that of the basin the gates are reopened and the basin allowed to fill. When the tide ebbs and sufficient head exists, the turbine units are again made operational and electrical power is produced as before.

III. PRESENT ENVIRONMENT

A. General

Cobscook Bay is an irregular coastal basin located on the eastern boundary of Washington County, Maine. The Bay is a complex of northwest-southeast directed finger-like bays. This complex is divided into an inner bay, consisting of Dennys and Whiting Bays, and an outer bay consisting of Straight, South, and East Bays. The division into inner and outer bays is marked by the narrow channel between Falls Island and Leighton Neck, known as Reversing Falls. The entire Bay probably had its origin in river valley submergence.

The most notable oceanographic feature in the Cobscook Bay area is the exceptionally large tidal reach. Tidal amplitude in the Bay ranges from about 11 feet (neap tide) to about 26 feet (spring tide) with a mean of approximately 18 feet.

Salient features resulting from this high tidal amplitude are the development of extensive intertidal flats and high velocity currents through the relatively narrow channel connecting Cobscook Bay with the Bay of Fundy. About 17 billion cubic feet of water enter and leave Cobscook Bay semi-diurnally. The tidal cycle spans 12 hours 25 minutes, the extra 25 minutes being the difference between the lunar day and the solar day. This difference is important to the economics of tidal power. Since tidal power varies with the tides, tidal power is often completely out of phase with normal demand patterns.

The surface area of the Bay at high tide is about 40 square miles and at low tide about 21 square miles. There are 7 square miles of intertidal mud flats in Cobscook Bay. Except for the area near Eastport, the site chosen by the Pittston Company for a proposed oil refinery, there appears to be no reliable data concerning current velocities in Cobscook Bay.

Slightly more than 400 square miles of land drain into Cobscook Bay. The major runoff for the inner Bay is contributed by the Dennys River, Hardscrabble River, Hobart Stream, Orange River, and East Stream. The Pennamaquan River, Smelt Brook, and East Brook are major sources of runoff for the outer Bay. The total average annual discharge into the Bay is about 300 cfs, of which the Dennys River accounts for 136 cfs.

B. Physical and Chemical Properties

As indicated, the volume of fresh water entering Cobscook Bay compared to the total volume of water is rather small, resulting in relatively high salinities. Salinities normally are in excess of $30^{o}/00$ and generally uniform throughout the water column except for extreme peripheral parts of the Bay, where the influx of fresh water is greatest. Salinity varies with the magnitude of river discharge, and thus is usually lowest in spring.

Water temperatures vary seasonally ranging from 0.6°C in winter to 14°C in fall. As with salinity, temperatures remain fairly constant with depth.

Dissolved oxygen concentrations range between 6 ppm and 10 ppm, and are usually in the order of 8-9 ppm. There is little variation with depth and essentially the entire water column is saturated with oxygen.

Uniform depth distribution of the above parameters results from the generation of high velocity tidal currents through the restricted channel connecting Cobscook Bay with the Quoddy Region and through the channel within Cobscook Bay known as Reversing Falls. This results in vertical mixing of the water mass and prevents stratification of the water column.

Little information has been gathered concerning inorganic nutrients; e.g., phosphates, nitrates, and silicates. Apparently, however, these nutrients are present in sufficient concentrations so that they are not limiting factors in primary productivity. Reduced sunlight resulting from turbulence, suspended particulate matter, fog, cloudy days, and low water temperatures appear to be the main factors limiting primary productivity in the marine environment of the Passamaquoddy area.

C. Habitats

The marine ecosystem of the Cobscook Bay area can be subdivided into a number of habitat types. It is not possible (nor desirable) to treat each of these in great detail here. For example, a recent study of the intertidal zone along the coast of Maine treated nine different habitats in detail, and emphasized that many more subdivisions could be defined (Larsen and Doggett, unpublished ms.). Each of the habitats is related energetically to the others, forming a complex trophic system whose specific relationships have yet to be determined.

Earlier workers considered the following habitats to be major subsystems of the study area: salt marshes; intertidal mud, sand and cobble flats; open water; rocky shorelines, headlands, and rock outcroppings; subtidal bottom; and high velocity channels. Each of these systems is described in some detail in TRIGOM Publication 2A (1973) and in the Final Environmental Impact Statement (FEIS), Vol. II, prepared by the U.S. Environmental Protection Agency for the proposed Pittston Oil Refinery. Only brief summaries are given here.

Saltmarshes are most common along the fringes of Cobscook Bay. They include the emergent vegetation and tidal creeks which are inundated semi-diurnally by salt water. Saltmarshes are among the most productive of habitats and are the source of much particulate organic matter.

Intertidal mud, sand, and cobble flats differ from one another in particle size composition. The type of sediment present is related to water velocity. Thus, the substrate in areas with strong currents is dominated by cobble; in areas of weak currents, by muds.

Open water habitats of the Bay include the entire water column. Communities here are based upon planktonic life and include all the organisms living in the water column subject to currents and tidal flows. The most abundant primary producers in the open water habitats of Cobscook Bay are diatoms.

Rocky shorelines, headlands, and rock outcroppings are high energy environments characterized by strong currents and hard substrate. The prominent producers here are large attached seaweeds. There generally is a marked zonation on steep vertical grades.

Subtidal bottom habitats are found below the low tide line. The bottom types range from muds to rocks. In suitable shallow areas sunlight penetrates to the bottom, where eelgrass (*Zostera marina*) and benthic diatoms may florish.

High velocity channels are passages where currents range from 3 to 20 miles per hour or more. Fine sediments are swept from these areas. Encrusting organisms such as bryozoans and certain red algae may occur in abundance in these areas.

It is evident that the major habitat types can each be divided into several sub categories. For example, Weiss and Stence (1978) divided the bottom habitats of Cobscook Bay into seven different kinds, with the possibility of even further subdivision. At least in part, this wide variety of habitats accounts for the great species richness of this area.

It has been noted that the existing marine environment in the Cobscook Bay Region is in essentially the same state that it was about 100 years ago (Pittston FEIS).

IV. LIVING RESOURCES

A. General

Biological resources of the Passamaquoddy Region have received the attention of numerous researchers. Institutions that have conducted ecological and systemic work in the area and on its biota include: University of Maine, University of New Hampshire, Plymouth State College, Suffolk University, St. Andrews Biological Station, Marine Research Associates, Huntsman Marine Laboratory, Maine Department of Marine Resources, Bigelow Laboratories, and the Research Institute of the Gulf of Maine (TRIGOM). The most extensive work has been with marine invertebrates and shore birds in the Cobscook and Passamaquoddy areas.

A most notable biological feature of the Passamaquoddy area is its diverse and abundant marine biota. A recent checklist showing the marine biota of the lower Bay of Fundy shore, New Brunswick, included 1,485 plant and animal species in 22 phyla (Linkletter et al., 1977). There is little doubt that this list will be increased considerably as the area receives greater attention.

Despite their importance as inventories of the marine biota found in the area, species lists do not provide information concerning ecological interrelationships among the organisms listed or information concerning the abundance, distribution or life history of any species. Unfortunately, little research has been done in these important areas and little is known about the ecology of most species found in Cobscook Bay. Knowledge of these ecological details is necessary in order to make valid assessments of the potential impacts that might result from project implementation. Nor is information available regarding the specific routes through which energy and other important resources are channeled within this system. The system is obviously very diverse and productive, yet little is known about the specific ecological processes that contribute to the diversity and exceptional productivity of Cobscook Bay.

B. Biota

Organisms of primary ecological significance in Cobscook Bay can be divided into three main categories: plankton, nekton, and benthos.

1. Plankton: Planktonic organisms are those with very limited powers of locomotion. Plant plankton is termed phytoplankton and animal plankton, zooplankton. Some animals spend only part of their life cycle as plankters, these are termed meroplankton. Prominent in the last group are fish larvae and larvae of benthic crustaceans and molluscs.

There has been relatively little long-term sampling of plankton in Cobscook Bay. Most of the following discussion is based upon the report prepared by Legare and MacLellan (1959) for the International Passamaquoddy Fisheries Board Report to the IJC.

Diatoms are the predominant phytoplankters in the Passamaquoddy Region. In Cobscook Bay the spring bloom occurs in early June, while in Passamaquoddy Bay it occurs in April-May. Davidson (1934) reported a fall bloom in Passamaquoddy Bay but this was not observed by Legare and MacLellan (1959). To the contrary, the latter authors reported very small catches of phytoplankton in the fall. Composition of the catch showed great monthly variation, with dominant forms declining rapidly, or disappearing, shortly after maximum concentrations were attained. For example, in May 1959 the dominant diatoms belonged to the genus *Biddulphia* (95 percent) with species of *Thalassiosira* and *Chaetoceros* comprising most of the remainder, while in June 1958 the genera

Thalassiosira (75 percent) and Chaetoceros (20 percent) were numerically dominant and Biddulphia was virtually absent (Legare and MacLellan, 1959). According to the TRIGOM Report (1973), the best information on species most likely to be found in Cobscook Bay was presented by Gran and Braaud (1935). (See Table 10, page 65 of the TRIGOM Report for a list of dominant species.)

Zooplankton is dominated by copepods, both in the number of indivd- uals and the number of species. Six species of copepods accounted for 94 percent of the total number of copepods taken. Three of the six species, Calanus finmarchicus, Pseudocalanus minutus, and Centropages typicus, are thought to immigrate into the area from the Gulf of Maine and three, Tortanus discaudatus, Acartia clausi and Eurytemora herdmani, are thought to be endemic to the Quoddy Region. The first three are, by far, the more abundant, accounting for about 84 percent of the total catch of copepods. The most abundant copepod was C. finmarchicus which comprised 46 percent of the copepods taken.

Other zooplankton consists primarily of eggs, larvae, and junveniles of neritic or benthic species. Among these are the eggs and/or larvae of fish, crabs, euphausiids, mussels, barnacles, chaetognaths, and annelids. Legare and MacLellan (1959) listed 22 species of fish larvae, the most common being rock gunnel (Pholis gunnellus, listed as the rock eel), American plaice (Hippoglossoides platessoides, listed as sand dab), lumpfish (Cycloplerus lumpus), wrymouth (Cryptacanthodes maculatus), and sea snail (Liparis atlanticus).

Zooplankton in Cobscook Bay (and the entire Quoddy Region as well) showed a marked seasonal variation in relative abundance. Abundance was greatest in summer, when about 63 percent of the total annual catch was taken. In spring, only 6 percent of the annual total was taken, while in fall and winter 14 percent and 17 percent, respectively, were taken. The total catch of zooplankton in Cobscook Bay was about five times that in Passamaquoddy Bay.

Zooplankton underwent a diel vertical migration, being most abundant at 75-100m during daytime and in the upper 50m at night.

2. Nekton: Nektonic animals are free-swimming and are capable of controlling their physical location in both vertical and horizontal dimensions. These include fishes, squid, and mammals. Over 100 fish species have been recorded from the Quoddy Region (Linkletter et al., 1977). The number of these that actually inhabit Cobscook Bay is not known. Some species are of interest because they are harvested commercially in the Quoddy Region; but there is no way of assigning a definitive value to the fisheries resources of Cobscook Bay, as catch statistics pertain only to landings of fishes, not where the fish actually were taken. It does appear, however, that neither Cobscook Bay nor Passamaquoddy Bay have significant commercially fishable resources.

Finfish harvested commercially in Cobscook Bay include the following: Atlantic herring (Clupea harengus), the most important commercial species in the Quoddy area; Atlantic cod (Gadus morhua); haddock (Melanogrammus aeglefinus); and pollock (Pollachius virens). Recreational finfishes include winter flounder (Pseudopleuronectes americanus), redfish, or ocean perch (Sebastes marinus), American mackerel (Scomber scombrus), and Atlantic salmon (Salmo salar). The Atlantic salmon is one of the most highly prized sport fishes, and the Dennys River, which drains into inner Cobscook Bay, is the most important spawning area for Atlantic salmon in the United States. Usually, from 200 to 1,000 salmon ascend the Dennys River to spawn. The St. Croix River apparently produces few salmon because of obstructions and pollution.

Other anadromous fishes of minor recreational or commercial importance are the alewife (Alosa pseudoharengus), and rainbow smelt Osmerus mordax). The American eel (Anguilla rostrata), is a catadromous species of minor commercial importance. For a detailed discussion of commercial finfish resources in Cobscook Bay see the Pittston FEIS and Dow (1959).

The shortnose sturgeon (Acipenser brevirostrum), an endangered species, is quite common in the St. John estuary. Although its preferred habitat is fresh and brackish waters of large river systems, it is known to tolerate salinities as high as $30^{o}/00$. It is very possible that the shortnose sturgeon occurs in the project area, but we have not been able to find any record of such an occurrence.

Nine species of marine mammals are common to the Gulf of Maine - Bay of Fundy area and can be encountered in the Cobscook Bay area; an additional 12 species occur rarely or infrequently (Katona et al., 1975; Leatherwood et al., 1975). Two of the best areas on the Atlantic coast for observing whales and porpoises from land are Head Harbor Light, Campobello Island, Canada; and West Quoddy Head, Lubec, Maine (Katona et al., 1975). Table 1 lists the marine mammals of the area.

The harbor porpoise (Phocoena phocoena) is the most common marine mammal in the area. The Quoddy Region may be the center of the harbor porpoise population in the North Atlantic, especially in summer and early fall. Other ceteceans commonly seen are the fin (Balaenoptera physalus), minke (B. acutorostrata), humpback (Megaptera novaeangliae), and right (Eubalaena glacialis) whales. The minke probably is the most numerous and may be represented by nearly 80,000 individuals in the North Atlantic. It frequently has been reported in the Bay of Fundy and often approaches shore. The fin whale also has been seen in large numbers in the Quoddy Region. Right whales can be seen nearshore in the Quoddy Region, while humpback whales commonly are sighted in the Bay of Fundy. Fin whales use nearshore waters in the area from late spring to late summer and humpback whales are found farther offshore during summer.

Two species of seals regularly occur in the area, the harbor seal (Phoca vitulina) and gray seal (Halichoerus grypus). The harbor seal is more common than the gray seal. Harbor seals feed on fish throughout the water column, preying upon both pelagic and demersal species.

Harbor seals and harbor porpoises use the area for reproduction and as a nursery ground with the former maintaining a breeding population of several hundred individuals in Cobscook Bay. A breeding colony of gray seals once existed near Grand Manan Island but now only a small number remain. There are local, non-migrant populations of both the harbor seal and harbor porpoise that depend upon the area for food and shelter throughout the year. Most other marine mammals are found in the area in spring and summer, and migrate to more southerly waters in fall.

The toothed whales consume many nearshore and deepwater fish and cephalopods, while baleen whales feed upon small fish but mainly krill and copepods throughout the water column. Right whales feed primarily near the surface. Humpback and minke whales commonly feed below the surface and at midwater but occasionally near the surface, and the fin whale feeds near the middle of the water column.

The fin, humpback, right, sei, blue, and sperm whales are all listed as endangered species pursuant to the Endangered Species Act of 1973.

3. Benthos: Organisms living on or in the substrate are termed benthos. Here the biota is generally dominated by invertebrates. According to Dr. L.T. Spencer (TRIGOM, 1973) the invertebrate fauna of

the Cobscook Bay area consists mostly of boreal species. This boreal invertebrate fauna is widespread on both sides of the Atlantic and many species are cosmopolitan. In addition to boreal species, Arctic and warm temperate species also are found in Cobscook Bay. Although the faunas of Cobscook Bay and the coast of Maine are similar, the bay has more regions with a mud substrate than along the open coast, which results in faunal differences. Perkins and Larsen (1975) noted that 62 of the 359 species they collected in the area were unique to Eastern Washington County, Maine.

Major factors influencing the benthic faunal composition in the Quoddy Region include the large tidal range, the counterclockwise circulation in the Gulf of Maine produced by local weather patterns, and the available substrate types (Spencer in TRIGOM, 1973).

Near Eastport, Maine, the site for the proposed Pittston oil refinery, a sampling program was conducted to determine the nature of the benthic fauna. More than 200 families of benthic invertebrates were representated, from which 162 species were identified. Annelids (seaworms), molluscs (snails, clams), and arthropods (crabs, beach fleas) were taken in about equal proportions and collectively accounted for 87 percent of the invertebrates.

In intertidal areas, periwinkles, limpets, clams, and worms predominated. Worms were the most numerous in silt-clay subtidal areas, with chitons, clams, amphipods, brittlestar (Ophiura robusta), and sea urchins comprising most of the remainder. Rocky intertidal areas were dominated by snails. For a more detailed discussion of the benthos of the Cobscook Bay area see the Pittston FEIS (III-83 to III-87), and the TRIGOM Report (1973).

Several Representatives of each of the three major groups of benthic invertebrates are harvested commercially. Included among these are the softshell clam (Mya arenaria), sea scallop (Placopecten magellanicus), lobster (Homarus americanus), crabs (Cancer spp.), blue mussel (Mytilus edulus), sand worm (Nereis virens), blood worm (Glycera dibranchata), periwinkle (Littorina litorea), sea urchin (Strogylocentrotus droebachiensis), and northern shrimp (Pandalus borealis). Of these, the softshell clam provides the most important commercial invertebrate fishery. A detailed discussion of commercially important invertebrate resources in Cobscook Bay is given in the Pittston FEIS and Dow (1959).

V. ENVIRONMENTAL IMPACTS

A. General

Impounding all or part of Cobscook Bay will cause broad scale alterations in physical conditions of the area. These changes will, of course, produce a wide array of impacts upon the biological systems found in Cobscook Bay. Society will view some of these impacts as detrimental, some as beneficial, and others as being neither. It is obvious that the ecological changes attendant to implementing a tidal power project must be reckoned with, in addition to financial and engineering considerations, when evaluating the net benefits of such projects.

B. Assessing Impacts

Accurate assessments of potential impacts upon natural resources cannot be made without detailed knowledge of the system(s) involved and of both the biotic and abiotic interrelationships that exist therein. Most of the ecological information available for Cobscook Bay is in the form of lists of species known or thought to occur in the area. Thus, before realistic predictions of the probable impacts resulting from impoundment of all or part of Cobscook Bay can be made, scientific studies of the biological dynamics of the entire biota (not only those resources that have economic or recreational significance) must be conducted. Since there is little known about trophic relationships in Cobscook Bay, predicting ecological changes that will result from implementation of this, or any large-scale project, will be a formidable task. At best we can hope to predict only the nature of the impact. The rate of change and new equilibrium conditions are almost impossible to predict for such a large and complex system. Hence, it is imperative that great caution and sound judgment be exercised in developing tidal power. Committing renewable resources to such an irrevocable decision must be done only after every effort has been made to predict all potential effects, no matter how subtle or remote they may seem. Adverse impacts at any point in the trophic structure of a system may affect the entire system because of the complex pathways through which energy and nutrients flow.

C. Ecological Changes

Ecosystems and their biotic constituents do not remain static, but gradually change. This process normally occurs over long time scales, ranging from decades to millenia. When man intrudes upon such systems, the rate of change can be greatly increased and perhaps also its direction. A significant environmental modification, such as a tidal dam, would result in rapid changes and influence the availability of natural resources. The nature of abiotic changes that may result from damming all or part of Cobscook Bay, and how those changes will be manifested in the biotic environment are discussed below.

Environmental changes that may result from tidal power development depend upon project configuration, mode of generating power, and pool size. According to the Corps of Engineers, in their preliminary economic assessment of developing tidal power in Cobscook Bay, about 90 developmental alternatives were considered. This list was reduced to five alternatives, based upon economic considerations. Although the COE concluded that from engineering and construction points of view, the project was feasible, it did not meet the economic criterion the COE must use when evaluating such programs (benefit to cost ratios were all well below 1.00). Using a relative price shift analysis, two of the alternatives appeared to be marginally feasible. These analyses did not include ancillary benefits or the costs of addressing environmental concerns.

The five most economically favorable alternatives were all single basins with relatively large impounded areas and relatively small installed capacity. From an environmental point of view each of the five is similar to the others, differing only in the size of the impoundment. The largest impoundment uses essentially all of Cobscook Bay as a tidal basin and the smallest one impounds roughly the inner 75-80 percent of the Bay. A sixth alignment that would impound a much smaller area was later added to the list of alternatives considered for development. Because of the overall similarity of these proposed projects and the paucity of detailed ecological information, we have considered only the general impacts that would be expected from implementing such a tidal power project. Site specific impact predictions will be possible only after sufficient data are gathered from the areas under consideration. This is not to say that potential impacts at specific localities are apt to be unimportant. To the contrary, these impacts will likely be of prime importance and the need for detailed environmental studies of any areas being considered for development of tidal power must be stressed. Obviously, predicting impacts at a given locality in the absence of site specific data is risky at best.

The major environmental changes will result from the existence of the dam and its associated structures. However, there will also be modifications caused by construction activities; for example, cofferdams, dredging, placement of fill and disposal of spoil. Impacts upon the terrestrial environment would result from transmission lines, quarries and roads. Impacts upon the terrestrial environment are not within our purview and will not be treated herein.

1. Changes Due to Construction

Prominent environmental changes resulting from construction will be caused by dredging, dewatering, placing of rock fill, and disposing of dredged material.

Dredging and the placing of rock fill will have the greatest impact upon the benthos. Benthic organisms will either be removed with the dredge spoil or buried by the rock fill. The extent of these impacts will, of course, depend upon the abundance of benthic resources in the vicinity of dredging and fill operations. Bottom habitat also will be lost permanently when fill is placed for the dam. The extent of such losses depends upon the particular site chosen, as the dams differ in length. There also may be a temporary reduction of benthic resources in the area surrounding the actual site of dredging and filling.

Construction activities may also affect local current patterns, resulting in changes in sedimentation, scouring, and nutrient transport. Impacts resulting from such modifications depend upon their nature and extent, and upon living resources in the area at the time of construction. Before any meaningful assessment can be made, models that will depict these modifications must be developed.

Primary productivity, apparently limited by light penetration, also may be adversely affected by construction activities. The increased turbidity associated with dredging and placement of rock fill will reduce the degree to which sunlight can penetrate the water column and thereby reduce primary productivity. This of course, may result in a temporary decrease in productivity at all other trophic levels.

Zooplankton could be directly and adversely affected by the increase in suspended particulate matter. Since many are filter feeders, large amounts of suspended inorganic material may interfere with feeding mechanisms.

Since there appears to be no major finfish spawning population within Cobscook Bay, except for winter flounder (<u>Pseudopleuronectes americanus</u>) (Dow, 1959), most species are likely to decrease in abundance if movement into Cobscook Bay is curtailed by construction processes. Diadromous fishes will be adversely affected unless provision is made for their passage into or out of the Bay during construction. Of critical importance here are alewife, smelt, and Atlantic salmon. In recent years, there have been increasing numbers of Atlantic salmon running up the Dennys River to spawn. Unless proper fish passage facilities are provided, and construction activities are properly timed, the spawning migrations of these species could be disrupted.

Marine mammals probably will suffer only minor adverse impacts because of construction activities.

The magnitude and extent of impacts upon marine organisms from dredging depend upon factors such as the method of dredging, type of spoil, presence of toxic substances, volume of material, and current regime.

Impacts resulting from construction activities can be minimized by using suitable techniques and common sense. For example, sedimentation can be at least partially controlled by using the appropriate type dredge and, possibly, by surrounding the work area with some type of filtering apparatus. Also, work can be timed so as not to interfere with spawning seasons or migrations and dredge spoil may be disposed of on upland sites, which will prevent additional losses of benthic habitat and benthic resources.

2. Changes Due to the Dam and Associated Structures

Significant environmental changes will result from operation of the dam and associated structures. The principal effect of a dam in Cobscook Bay will be to alter the tidal regime and water circulation by attenuating tidal energy and thereby reducing the amount of water exchange. Other important environmental impacts are related to these changes.

In the tidal basin there apparently will be a decrease in the average tidal reach from about 18 feet to 12.5 feet, and a slight increase in the mean water level. Because of the reduction in tidal energy, mixing will not be as great and some stratification of the water column will occur. This stratification will lead to a wider range of surface temperatures and salinity and dissolved oxygen concentrations in the basin can be expected to decrease.

Sediment is greatly influenced by water movement and therefore will most likely be affected by the decrease in wave energy in the tidal basin. Sedimentation probably will increase in the tidal basin, which may have significant effects on the ecology of both benthic and planktonic organisms.

Development of tidal power may result in transient and permanent localized siltation. Many benthic organisms may not be able to survive a heavy deposition of sediment. Considerable attention should be given to the potential increases in sedimentation that might result from development of tidal power. To illustrate the potential magnitude of this problem, we quote from Risk et al. (1977): "Six years ago a causeway was constructed across the Avon River at Windsor, Nova Scotia. The decrease in water velocity caused by this obstruction has produced a mudflat immediately below the causeway, which has accreted more than 10m since construction". Those authors suggested that the above incident may be analogous to what might happen after construction of a tidal dam.

Other factors that will be affected by impoundment include hydrology, climatology, and water and sediment chemistry. Changes in the tidal regime will also affect the impact of fresh water discharge into the Bay. Since the drainage of fresh water into Cobscook Bay is quite small compared to tidal flushing, impacts from this source are expected to be minor. Nevertheless, investigation into this area is necessary before the changes can be predicted with any certainty.

Ice formation potential will increase because of the reduced tidal range and wave energy in the basin. Increased ice cover would modify currents and cover mud flats and benthic organisms. Climate regimes are greatly influenced by the interaction of the atmosphere and the sea. Changes in sea surface temperature and ice cover can have localized effects upon the occurrence of fog, precipitation, and the duration of freezing temperatures.

Changes in the physical environment will influence water and sediment chemistry and through them the biota of the ecosystem. Little is known about these features of Cobscook Bay.

Impoundment of all or part of Cobscook Bay will result in the loss of an appreciable amount of intertidal habitat. Following dam construction, some of the area normally exposed at low tide will be covered with water throughout the tidal cycle. This will have a major impact upon shore birds found in the area. These intertidal areas represent major feeding grounds for waterfowl found in Cobscook Bay, particularly in fall and spring. Birds that winter over in Cobscook Bay would face the greatest adverse impact from the loss of intertidal forage areas.

When operational, the dam would restrict the movements of organisms into or out of Cobscook Bay. Since passage into or out of the Bay would occur only when filling gates or navigation locks were open, planktonic animals would be least restricted and large marine mammals would be most restricted in their movements.

Mammals in the Bay would be trapped there, while those outside would not be able to enter. As stated earlier, the harbor seal maintains a breeding population in Cobscook Bay, and the possibility of a major adverse impact upon a population of harbor seals entrapped in the Bay must be given consideration. Several of the larger whales known to occur in the area are on the endangered species list. Any potential adverse impacts upon endangered species must be reviewed in detail because of the protection afforded them by the Endangered Species Act.

The harbor porpoise is thought to be declining in numbers throughout its range, except along the northeast coast, and the population centered in the Quoddy Region may be the last healthy Atlantic population (Pittston, FEIS III-109). Some harbor porpoises found in Cobscook Bay may not be migratory and therefore depend upon the area for food and shelter throughout the year. Adverse impacts upon this species may affect the Quoddy population and further endanger its existence.

It is difficult to predict the effects of impoundment upon planktonic organisms. Presumably their migrations into and out of the Bay would not be greatly affected. However, the change in tidal flushing may cause a slight reduction in the numbers of plankters carried into the Bay. The change in tidal amplitude, flushing rate, and temperature regime also may result in changes in species composition and relative abundance. Before any reasonable predictions can be made, more detailed information on the nature of these changes is necessary, as well as the environmental preferences and tolerances of the involved species to the anticipated conditions.

The expected reduction in turbidity from decreased mixing will likely result in increased water clarity and may cause an increase in primary productivity. The slightly higher mean water level will provide additional habitat for planktonic organisms, which may allow for an additional increase in primary production.

Benthic organisms may be impacted in several ways. If sedimentation increases on either side of the dam, non-motile benthic organisms may be destroyed by being covered with sediment. In the vicinity of the dam, periodic dredging may become necessary, resulting in the destruction of benthic organisms and disruption of benthic habitats. If sedimentation involves different particle sizes than those composing the present substrate, changes in species composition can be expected. The loss of intertidal area will cause a reduction in the abundance of benthos that colonize intertidal areas. Particularly notable here is the soft shell clam, the most important commercial species in Cobscook Bay. Clam production would likely decrease by about half. The new clam zone would not be productive for about ten years, after which it is expected that total clam production would recover to that before impoundment (Medcof, 1962).

The loss in intertidal area will be accompanied by a change in area and location of saltmarsh. As a result of the lower tidal reach, the intertidal zone will not only be reduced in extent but also will shift to a lower elevation. Since saltmarshes are formed on the shoreward edge of the intertidal zone, it follows that saltmarshes in the tidal basin will shift to a lower elevation.

Fishes will be hindered in their movements into and out of Cobscook Bay after construction of the dam. Diadromous fishes would be prevented from entering the Bay and running up rivers and streams to spawn unless appropriate fish passage facilities are incorporated into the project. Resident fishes (except for winter flounder) apparently do not spawn to any great extent in Cobscook Bay. These species must maintain their populations by migrant individuals that enter the Bay. The tidal dam would interfere with migrations of different species in different degrees. For example, herring would be able to enter into the Bay through the filling gates or boat lock when they were opened. Since the gates will be open only a few hours a day, the influx of individuals would likely be reduced. Most species of groundfish breed outside of the area and migrate into and out of the area. Groundfish probably will encounter more of a problem in crossing the dam unless passage facilities are available near the bottom. Non-breeding populations of groundfish inside the basin are expected to decline considerably and most species will not be abundant enough to be exploited commercially. Winter flounder populations may increase in size in the tidal basin.

Mortality at the turbines dependsupon many factors. There is little information concerning the effects of turbines on plankton, finfish, or shellfish. It is likely that at least some individuals will not survive passage through the turbines. Again, this is an area where much additional investigation is needed before reasonable assessments of potential impacts can be made.

D. Changes Resulting From Biological Interactions

The above discussion of potential impacts from development of tidal power deals with the effects of physical changes in the environment upon individual species or groups of species that are found in the same habitat. It is ecological naivete to assume that impacts upon one species in a system will have no effect upon other species in the system. For obvious interactions, e.g., predator-prey interactions, we may be able to predict how impacts upon one of the species will affect the other(s). In most biological systems, however, there are both direct and indirect interactions between many species. Obviously, changes in one species will affect each of the others that interact with it.

In order to predict the nature and extent of these changes, a fuller understanding of the ecological relationships between the various species of a system is necessary. There is very little information of this kind available for Cobscook Bay. To fully understand the ecology of a complex system such as that found in Cobscook Bay it is necessary to know the pathways through which energy and nutrient materials flow through that system. It is imperative to possess such knowledge so that accurate predictions can be made of the changes that will occur if large scale modifications of the physical environment are effected. If accurate assessments cannot be made of the probable impacts to a system it will not be possible to weigh the benefits against the losses to society.

IV. AQUACULTURE

Presumably not all marine organisms will be adversely impacted by changes resulting from the development of tidal power, and some species may in fact benefit from such development, particularly species that may be suitable for use in aquaculture programs. There have been several reports concerning aquaculture in Cobscook Bay, but none based upon experimental field work. Until suitable studies are conducted, the benefits of aquaculture must be accepted as being speculative at best. This is not to say that such ventures will not be commercially successful but simply that more rigorous field studies are needed.

The most notable works on aquaculture in Cobscook Bay are Foster (1976), Shipman (1974), and Weiss and Stense (1978). Foster and Shipman both suggested that rainbow trout would be the most suitable species for cultivation under the conditions prevailing in Cobscook Bay; a seven to eight month growing season and relatively low temperature. Both Foster and Shipman suggested that coho salmon would be suitable for controlled cultivation in Cobscook Bay. Foster suggested that Atlantic salmon, the soft shell clam and the European flat oyster (Ostrea edulis) also would be suitable in this regard. The two authors differ somewhat in their outlook regarding feasibility of aquaculture in the Bay. Shipman stated that development of an aquaculture program in Cobscook Bay would present many unusual problems. Foster on the other hand made no indication of unusual difficulties that might attend ventures in commercial cultivation of marine organisms in Cobscook Bay.

According to Shipman, problems facing attempts at aquaculture in Cobscook Bay are: the short growing season, relatively cold water, absence of nearby freshwater ponds with winter or spring temperatures high enough for incubation and maintenance of young stages of either rainbow trout or coho salmon, the absence of information concerning diseases, and depletion of stocks due to transportation and handling.

Foster estimated that aquaculture ventures (both extensive and intensive) could result in a total annual value of about $18 million for the combined expected yield of soft shell clams, European flat oyster, coho salmon and rainbow trout, with the last species accounting for about 60 percent of the total. Shipman predicted an annual net benefit of about

$2 million in the 1980's for harvests of coho salmon and rainbow trout.

These significantly large dollar values warrant indepth analysis of the feasibility of aquaculture in conjunction with the development of tidal power in Cobscook Bay. Weiss and Stence indicated that several species of both finfish and shellfish would be suitable for aquaculture and management. However, they did not consider the effects of tidal power development in their study.

VII. SUMMARY AND RECOMMENDATIONS

We have argued elsewhere that the Cobscook Bay area is unique, productive, and perhaps most important, relatively pristine. This is one of the very few large coastal areas within the continental United States that has not been altered to any great degree by man's activities. Cobscook Bay is relatively free of pollutants generated by mankind and is comparatively undeveloped commercially. We believe that the uniqueness of this area is a feature well worth preserving. The local marine ecosystem and benefits derived therefrom have great national and international value. The cost of risking these resources must be carefully weighed against the potential benefits that might be derived from modifying such a unique system. We realize that it is difficult to weigh marine ecosystem values against other considerations, particularly economic criteria. However, we have been charged with the mandate of protecting living marine resources, and we believe that preserving the habitats of such resources is the most effective way of discharging this duty.

In summary, Cobscook Bay is a unique area with diverse habitats, fed and drained by great tidal movements twice each day. This wide array of habitats houses a diverse assemblage of marine plants and animals, ranging from diatoms to whales. A wide variety of commercial and recreational activities are founded upon the marine resources of the area.

The tidal reach in Cobscook Bay is the most extensive within the continental United States.

Perhaps the most noteworthy aspect of this complex ecosystem is the occurrence of cold water and deepwater organisms in the harbor at Eastport. (Presumably this phenomenon occurs elsewhere in the Bay, but we have not been able to document it.) As a result of the turbulent hydrographic conditions, low water temperatures typical of the deep waters of the Gulf of Maine are found at the dock throughout most of the year. Oceanic euphausiids, copepods, and other invertebrates generally found only offshore are present in abundance. Large numbers of ocean perch, or redfish (Sebastes marinus) occur in the surface waters off Eastport (Kelly and Barker, 1961). This species is abundant in deeper waters of the North Atlantic and is fished commercially at depths of 50-200 fathoms. Eastport is the only location in the North Atlantic where ocean perch are known to occur at the surface in inshore waters.

Krill (Meganyctiphanes norvegica), another cold water offshore marine organism, is often present in vast numbers. These euphausiids are eaten by redfish, several whales, and many species of ground fish. Although their role in open ocean systems is well known, we know very little about the ecological role of krill in Cobscook Bay.

In light of the rather large gaps in knowledge of the ecology of the area, it is not possible at this time to provide a detailed impact assessment of the development of tidal power in Cobscook Bay. The risks are largely unknown and the benefits relatively minor. It appears that environmental risks from project implementation are substantial and the benefits relatively minor. However, we realize that this analysis is largely subjective and that additional environmental site specific studies are necessary before adequate assessments can be prepared. We recommend that large-scale implementation of tidal power in Cobscook Bay be deferred until such time as more extensive ecological information is available.

Long-term studies should be conducted before any decisions are made. Ideally, information from all seasons and several years should be gathered so that variations within the system in both time scales can be determined.

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Table 1. Occurrence of marine mammals near the project area site.

Common name	Scientific name
Common	
Harbor porpoise	*Phocoena phocoena*
Pilot whale	*Globicephala melaena*
White side dolphin	*Lagenorhyncus acutus*
Fin whale	*Balaenoptera physalus*
Minke whale	*Balaenoptera acutorostrata*
Humpback whale	*Megaptera novaeangliae*
Right whale	*Eubalaena glacialis*
Harbor seal	*Phoca vitulina*
Gray seal	*Halichoerus grypus*
Rare	
White beaked dolphin	*Lagenorhynchus albirostris*
Common dolphin	*Delphinus delphis*
Killer whale	*Orcinus orca*
Bottlenosed dolphin	*Tursiops truncatus*
Gray grampus	*Grampus griseus*
Striped dolphin	*Stenella coeruleoalba*
Beluga	*Delphinapterus leucas*
Sei whale	*Balaenoptera borealis*
Blue whale	*Balaenoptera musculus*
Sperm whale	*Physeter macrocephalis*
Pygmy sperm whale	*Kogia breviceps*
Northern bottlenosed whale	*Hyperodon ampullatus*

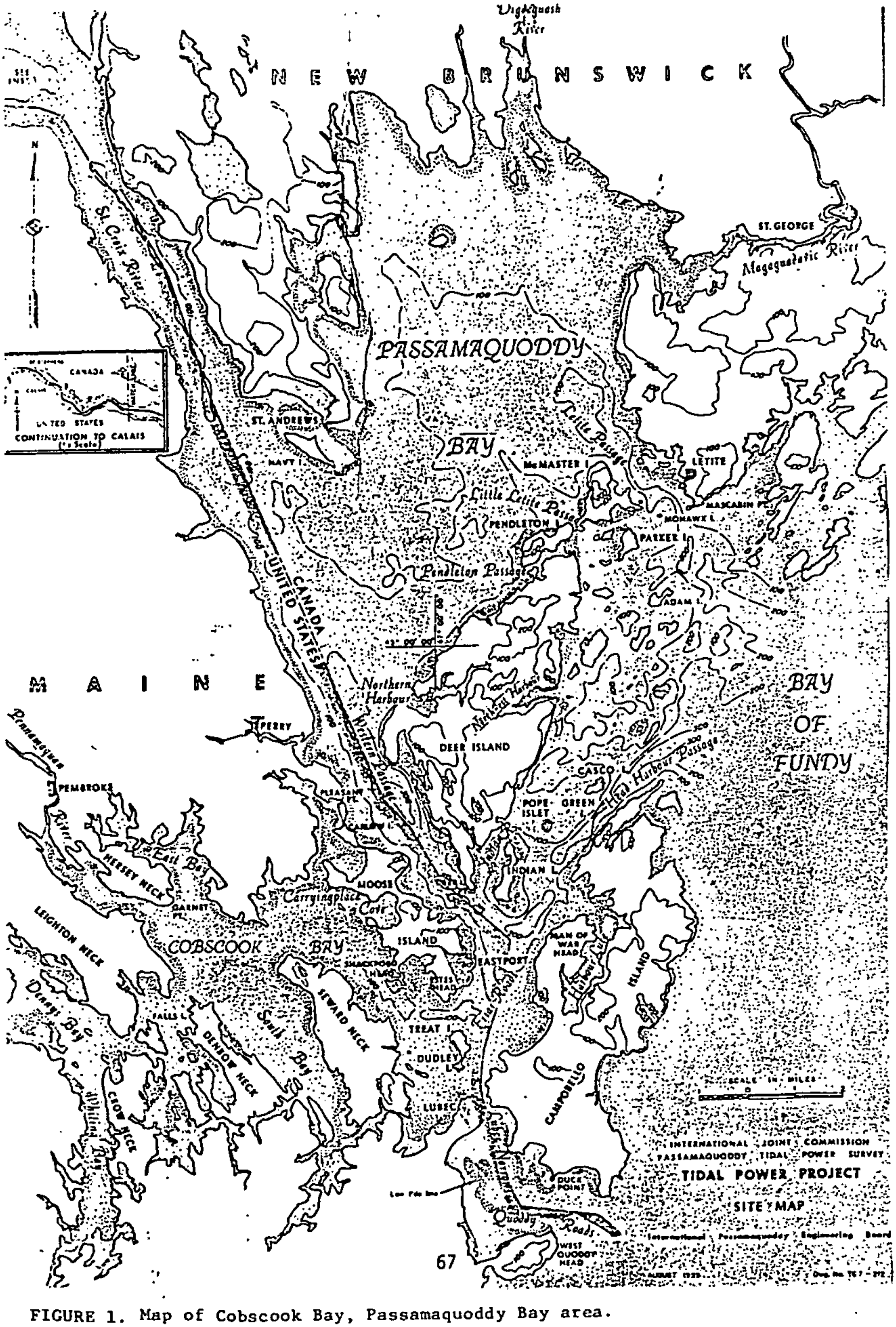

FIGURE 1. Map of Cobscook Bay, Passamaquoddy Bay area.

HABITAT UTILIZATION BY SOUTHWARD MIGRATING SHOREBIRDS

IN COBSCOOK BAY, MAINE DURING 1979

Project Report

by

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INTRODUCTION

Shorebirds (Order Charadriiformes), which include sandpipers, plovers, turnstones, and phalaropes, comprise one of the most important bird groups inhabitating the Maine coast. Thirty-nine species (Table 1) have been reported to occur in Maine but only 8 of these are resident breeders. Most shorebird species frequenting the Maine coast are long-distance migrators, traveling each year from nesting sites in the North American arctic to wintering areas in Central and South America.

Southward migration begins soon after hatching in the arctic. For most species, adults initiate migration first to coastal staging areas. The precocial young care for themselves and initiate their migration a few weeks later. Recent studies (e.g. McNeil and Burton 1973) have shown that migration from North American staging areas to South America involves a non-stop trans-oceanic flight of several thousand miles. Some species (e.g. Hudsonian godwit) depart directly from James Bay in Canada. Whimbrels, white-rumped sandpipers, golden plovers, and black-bellied plovers leave from their primary staging areas in the Canadian maritime provinces. Still others, semipalmated sandpipers, semipalmated plovers, sanderlings, and lesser yellowlegs depart from coastal staging areas ranging from the Gulf of St. Lawrence south to Cape Hatteras. Short-billed dowitchers depart primarily from the mid-Atlantic coast.

Therefore, shorebirds are dependent on coastal staging areas for food and rest to accumulate fat reserves for their trans-oceanic flight. During their 2- to 3-week stay at staging areas, shorebirds feed heavily on marine invertebrates living in intertidal areas and nearly double their fat-free weight. Shorebirds greatly impact on these prey resources (Schneider 1978), and annual variations in prey abundance may affect survival during migration. Similarly, man-induced impacts that reduce prey availability may adversely affect shorebird populations.

Table 1. Status of shorebird species known to occur in Maine (Vickery 1978).

FAMILY	SPECIES	COMMON NAME	STATUS
Haematopodidae	Haematopus palliatus	American Oystercatcher	I T
Charadriidae	Pluvialis dominica	American golden plover	I T
	P. squatorola	Black-bellied plover	C T
	Charadrius vociferus	Killdeer	C B
	C. semipalmatus	Semipalmated plover	C T
	C. melodus	Piping plover	P B
	C. alexandrinus	Snowy plover	I T
Scolopacidae	Limosa haemastica	Hudsonian godwit	I T
	L. fedoa	Marbled godwit	I T
	Numenius borealis	Eskimo curlew	E T
	N. phaeopus	Whimbrel	C T
	Batramia longicauda	Upland sandpiper	U B
	Tringa melanoleuca	Greater yellowlegs	C T
	T. flavipes	Lesser yellowlegs	C T
	T. solitaria	Solitary sandpiper	C B
	Catoptrophorus semipalmatus	Willet	C B
	Actitis macularia	Spotted sandpiper	C B
	Arenaria interpres	Ruddy turnstone	C T
	Philohela minor	American woodcock	C B
	Capella gallinago	Common snipe	C B
	Limnodromus griseus	Short-billed dowitcher	C T
	L. scolopaceus	Long-billed dowitcher	P T
	Calidris canutus	Red knot	U T
	C. alba	Sanderling	C T
	C. pusilla	Semipalmated sandpiper	C T
	C. mauri	Western sandpiper	P T
	C. minutilla	Least sandpiper	C T
	C. fuscicollis	White-rumped sandpiper	C T
	C. bairdii	Baird's sandpiper	I T
	C. melanotos	Pectoral sandpiper	C T
	C. maritima	Purple sandpiper	C T
	C. alpina	Dunlin	C T

Table 1. continued

FAMILY	SPECIES	COMMON NAME	STATUS
	Micropalama himantopus	Stilt sandpiper	I T
	Tryngites subruficollis	Buff-breasted sandpiper	I T
Phalaropodidae	Phalaropus fulicarius	Red phalarope	C T
	P. lobatus	Northern phalarope	C T
	P. tricolor	Wilson's phalarope	C T
Recurvirostridae	Himantopus himantopus	Black-necked stilt	I T
	Recurvirostra americana	American avocet	I T

C - common, populations secure and habitats are not severely threatened

U - uncommon, species vulnerable because it exists in such small number or is so restricted throughout its distribution that it may become endangered if its total population declines or if environmental conditions deteriorate

E - endangered, species whose prospects for survival are in jeopardy

P - peripheral, species that extends into the state but is at the edge of its geographic distribution

I - irregular, species has been recorded though a population does not regularly occur each year in the state

B - breeding bird

T - transient, species only occurs as a sping or fall migrant, or both

W - wintering bird, present during January and February of every year

In addition to these shorebird species being a resource of considerable biological and aesthetic value, U.S. Fish & Wildlife Service (in press) suggested that the utilization of particular coastal habitats by shorebirds may indicate the relative productivity or quality of an area. Much of the literature concerning migratory shorebirds supports this hypothesis, but it is obvious (e.g. Smail 1970) that there are many variables to consider in accounting for the abundance or absence of a particular species in a given location. Smail was also correct in his assessment that the relative importance of variables is hard to evaluate, and consequently, little work has been done on this topic. This lack of knowledge is particularly important in a practical sense when an attempt is made to develop criteria to conduct an *a priori* evaluation of intertidal environments as potential habitats for migratory shorebirds.

Therefore, work was initiated in the Cobscook Bay area of eastern Maine in 1979 to (1) inventory the availability of intertidal habitats, (2) document patterns of use of intertidal habitats by migratory shorebirds, and (3) evaluate selected environmental characters as determinants of preferred intertidal habitats by migratory shorebirds.

This project report describes the occurrence, distribution, and habitat utilization by shorebirds using Cobscook Bay as a staging area during the 1979 southward migration. Specific objectives were to (1) locate and describe shorebird feeding and roosting areas in Cobscook Bay, (2) quantify species composition, seasonal abundance, and phenological patterns of southward migrating shorebirds in Cobscook Bay, (3) inventory intertidal invertebrates to describe foods available for shorebirds, and (4) correlate shorebird abundance with habitat characteristics (ie. tidal fluctuations and invertebrate density).

ACKNOWLEDGEMENTS

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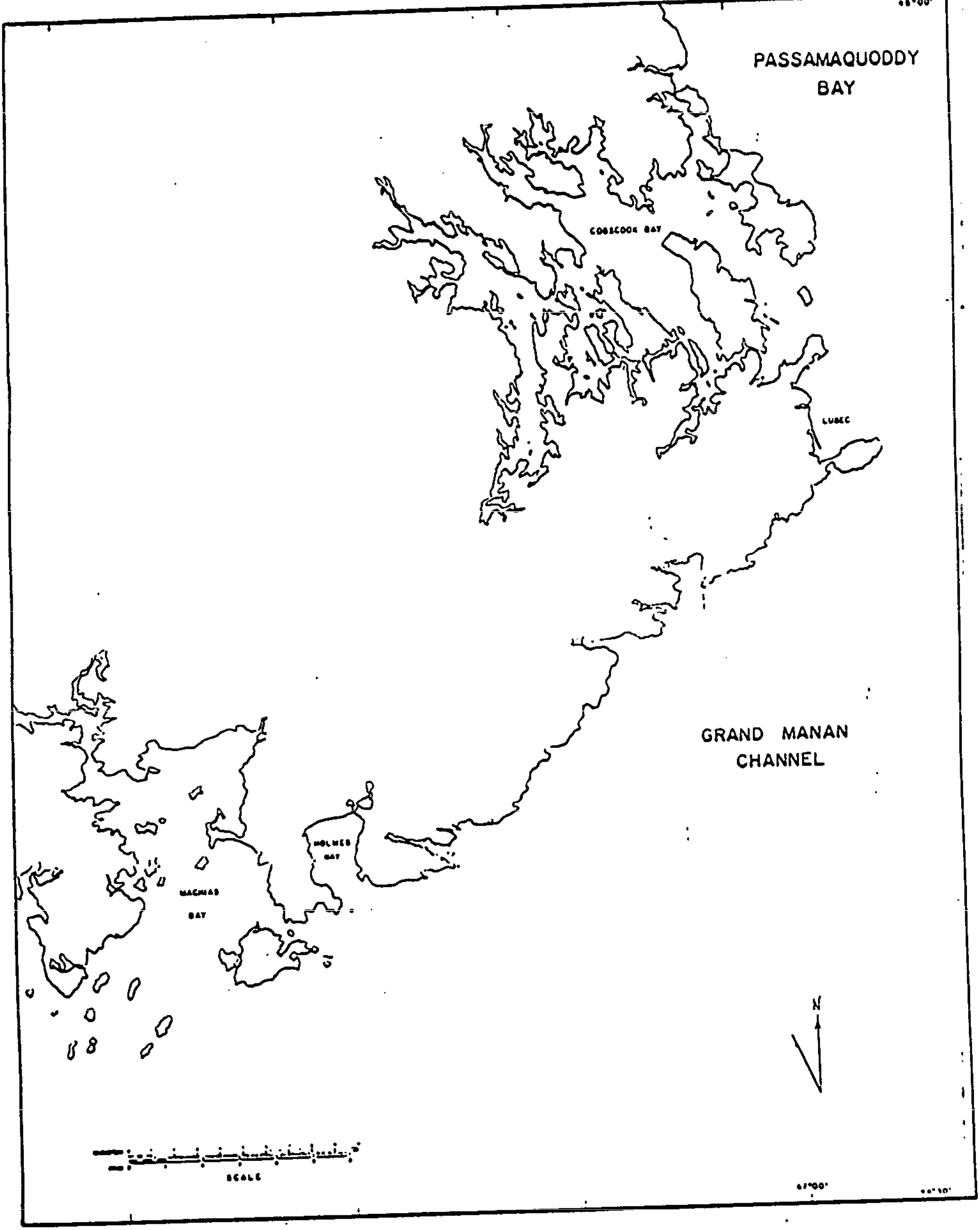
Jay Barber, Patrick Corr, Ellen Snyder, and Leonard Young assisted with field studies. Michael Donovan, Gay Muhlberg, Eric Thomas, and Donald Ward helped to sort invertebrates in substrate samples. Arthur West, Laboratory Directory, the R. S. Friedman Laboratory and his staff graciously assisted with providing room and board. Stuart Fefer, U.S. Fish and Wildlife Service, provided advice throughout the summer, and Norman Famous provided advice, field assistance, and field observations for inclusion in this report. We thank these individuals for their contributions. The contributions of Norman Famous were particularly valuable.

STUDY AREA

Cobscook Bay is a large, complex estuary of the Dennys, Whiting, and Pennamaquan Rivers in the easternmost part of Maine (Figure 1). The bay is surrounded by low rolling hills and undeveloped shorelines with open fields and spruce-fir forests. Deer Island and Campobello Island, New Brunswick, are adjacent to the mouth of the bay opening to the larger Passamaquoddy Bay and the Grand Manan Channel.

Tidal amplitude ranges from 3.8 to 7.8 meters. Due to the great tidal

Figure 1. Cobscook Bay area in eastern Maine.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BAY
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HOLMES
BAY
MACHIAS
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SCALE

amplitude, extensive mudflats are exposed throughout the bay at low tide. Tides of the inner bay are delayed about 1 hour in comparison to those of the outer bay because of the restricted area for flow of water. Swift tidal currents cause mixing of waters resulting in little variability of salinity throughout the bay.

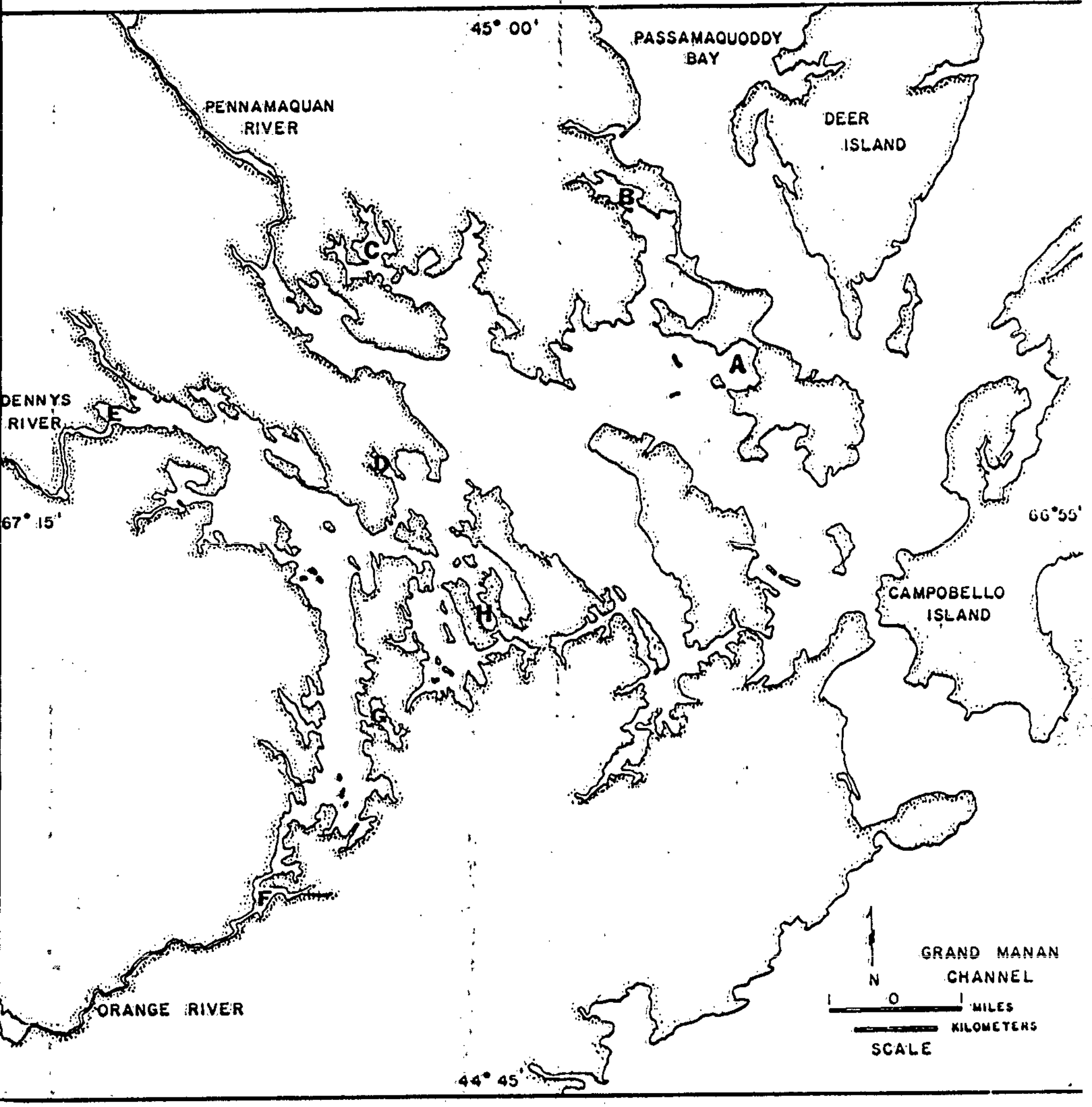
Three energy-related industrial developments are proposed for construction in the Cobscook Bay area that would cause major impacts if implemented. The Passamaquoddy project to use tidal water to generate electrical power was first evaluated in 1936 by the U.S. Army Corps of Engineers. It was terminated at that time but may become economically feasible as the cost of petroleum rises. The Passamaquoddy Indian Reservation is studying the possibility of constructing a small-scale tidal power generating facility in Half Moon Cove near Eastport. Lastly, the Pittston Corporation has proposed the construction of an oil refinery and deep-water marine terminal near Eastport that would refine 250,000 barrels of crude oil per day.

METHODS

Draft national wetland inventory maps of Cobscook Bay were field checked for accuracy. Corrections were made, and the maps were redrafted. Eight intertidal mudflats were arbitrarily chosen (Figure 2) for intensive study as potential shorebird feeding areas.

Upper Half Moon Cove and Carringplace Cove in the outer bay were known to be extensively used by shorebirds. Sipp Bay, Nutter Cove, and Long Cove were chosen to represent mid-bay mudflats. The Dennys River and Whiting River outlets and Carringplace Cove (inner bay) represented mudflats in the inner bay. Patterns of historical usage of mid- and inner-bay mudflats by shorebirds were not known.

Figure 2. Intensive study sites in Cobscook Bay: (A) Carringplace Cove (outer bay); (B) Upper Half Moon Cove; (C) Sipp Bay; (D) Long Cove; (E) Denny's Bay; (F) Whiting Bay; (G) Carringplace Cove (inner bay); and (H) Nutter Cove.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H
CAMPOBELLO
ISLAND
G
F
GRAND MANAN
CHANNEL
N
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MILES
KILOMETERS
SCALE
ORANGE RIVER
44° 45'

On each mudflat a linear transect was arbitrarily established perpendicular to the water line and extended from the high water mark to the low water level or the center of the mudflat. These transects varied in length between 80 and 400 m depending upon the extent of exposed substrate. Transects were marked at 20 m intervals using wooden stakes. A 10 x 10 m plot was randomly located along an imaginary line running at right angles to the permanent transect 50 m on either side of every permanent marker.

Each study area was observed for 3 tidal cycles (2 in July and 1 in August). Binoculars (7 x 35 mm) and spotting scopes (15-60 power) were used to make observations. Shorebirds were counted by species on falling tides in each exposed, permanently-marked plot at 20-minute intervals. Observations were terminated when shorebirds left the area of the study plots or when weather or darkness precluded making accurate species identification and counts. In order to make shorebird counts comparable, an index of abundance was calculated for each plot and time-interval using the technique reported by Burger et al. (1977).

Cores of the substrate were taken at the Carryingplace Cove (outer bay), Half Moon Cove, Sipp Bay, Dennys River, and Whiting River study areas in mid-August. Ten cores, each 4.7 cm diameter by 10 cm deep, were taken from the periphery of each permanently-marked plot. Cores were taken immediately after plots were exposed by receding tides. Cores were washed through a 1-mm sieve. Organisms and sediment retained by the sieve were stored in vials of buffered 10 percent formalin. Rose bengal dye was added to each vial to stain the organism for easier sorting. Organisms were separated later according to species, whenever possible, and counts of invertebrates made.

Cobscook Bay was searched to locate shorebird feeding and roosting areas. Once these areas were identified, shorebirds were censused every 10 days until

September 30. Counts were made at roosts at high tide and at feeding areas on a falling tide. The small sandpipers (least, western, and semipalmated) were collectively termed peeps, because they are difficult to differentiate at a distance. Ages of shorebirds were determined by plumage patterns.

RESULTS AND DISCUSSION

FEEDING AND ROOSTING SITES

Use of feeding and roosting sites in and around Cobscook Bay (Figure 3) is described in this section. Numbers associated with species are maximum values obtained from censuses during the southward migration.

Lubec Area

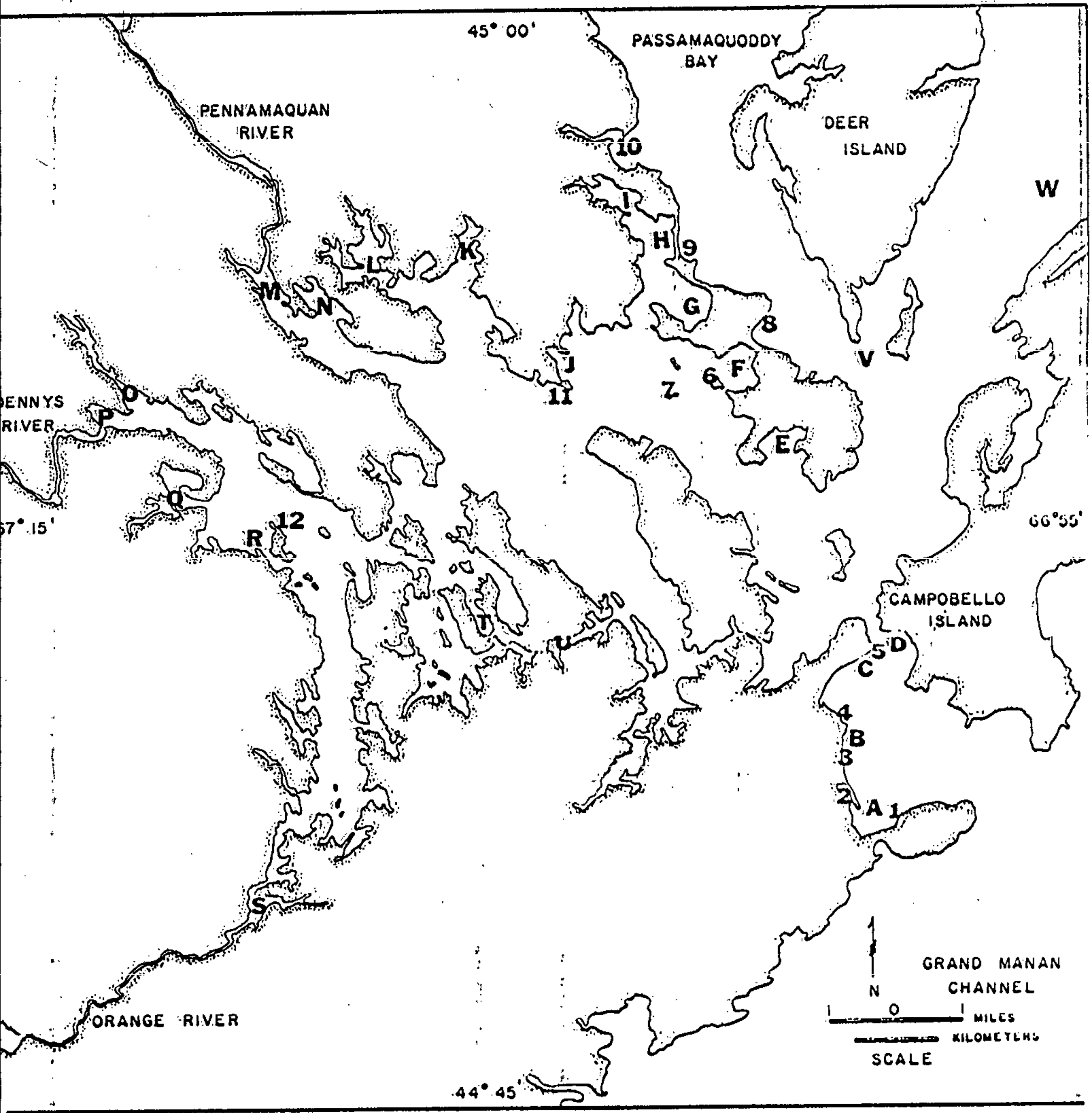
The Lubec area includes a variety of coastal areas which open to the Grand Manan channel and is well known to local bird watchers as an area utilized by high numbers of shorebirds in fall and as an area with a high likelihood for sightings of uncommon or rare species (N. Famous, personal communication).

Lubec Flats

The Lubec flats extend from the town of Lubec southward to West Quoddy Head. Intertidal areas (Appendix I) vary from being comprised of sand to liquid mud. The shoreline is a mixture of sand beaches and rocky areas. This area was used by feeding semipalmated sandpipers (2500), semipalmated plovers (200), and black-bellied plovers (200). Also common were least sandpipers, sanderlings, knots, ruddy turnstones, whimbrels, white-rumped sandpipers, and greater and lesser yellowlegs.

Shorebirds from the Lubec flats roosted at several well-established sites. These include the Lubec Medical Center, the Lubec Center beach, and the Lubec

Figure 3. Shorebird feeding (letters) and roosting (numerals) sites in Cobscook Bay: (A) Lubec flats; (B) Lubec Center beach; (C) Town of Lubec; (D) International Bridge flats; (E) Broad cove; (F) Carringplace cove (outer bay); (G) Lower Half Moon cove; (H) Carlow island; (I) Upper Half Moon cove; (J) Birch point; (K) East bay; (L) Sipp bay; (M) Pennamaquan river; (N) Hersey cove; (O) Hardscrabble river; (P) Dennys river; (Q) Hobart stream; (R) Edmunds flats; (S) Whiting bay; (T) Nutter Cove; (U) Federal Harbor; (V) Western Passage; (W) Head Harbor passage; (1) Lubec gravel bar; (2) Lubec salt marsh and sand spit; (3) Lubec Center beach; (4) Lubec Medical Center; (5) Town of Lubec; (6) Mathews island; (7) Goose island; (8) Johnson cove; (9) Carlow island; (10) Gleason cove; (11) Birch point; and (12) Hallowell island.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gravel bar. Shorebirds feed throughout the Lubec flats, but areas adjacent to the gravel bar roost received the most intensive feeding activities.

Lubec Center Beach and Medical Center

This area was used regularly by feeding semipalmated sandpipers (300), semipalmated plovers (423), ruddy turnstones (6), sanderling (115), and knots (less than 20). This area was also important for roosting shorebirds. The Center beach was used by semipalmated plovers (450), semipalmated sandpipers (4900), sanderlings (100), black-bellied plovers, and ruddy turnstones. The Medical Center was used consistently by sanderlings (75), semipalmated sandpipers (5000), semipalmated plovers (1100), and knots (15-20). The Medical Center was the only known feeding and roosting area for knots in Cobscook Bay. Black-bellied plovers (61) and ruddy turnstones (5) also used this area for roosting.

Town of Lubec

Flats in the town of Lubec were used by feeding semipalmated sandpipers (800) and semipalmated plovers (300). Shoreline in the town was even more important for roosting sanderlings (300), semipalmated sandpipers (4000), semipalmated plovers (750), black-bellied plovers (20), and ruddy turnstones (14).

Lubec Gravel Bar

This was the most important roost in the Cobscook Bay area for black-bellied plovers (2000) and ruddy turnstones (125). It was of lesser importance to semipalmated sandpipers (4500) and semipalmated plovers (150). Least sandpipers and yellowlegs also roosted on this site.

Lubec Salt Marsh and Sand Spit

This was an important roosting area for semipalmated sandpipers (1000-2000), greater and lesser yellowlegs (<25), and least sandpipers. Whimbrels and black-bellied plovers also roosted here.

International Bridge Flats

Three hundred to 400 semipalmated sandpipers regularly used these and nearby flats along the southern shore of Campobello Island.

Broad Cove

This was used by feeding semipalmated sandpipers (1420), semipalmated plovers (265), and black-bellied plovers (73). Sanderlings, ruddy turnstones, and lesser yellowlegs also fed here.

Carringplace Cove

Carringplace cove included flats characterized by muddy sand and scattered rocks and boulders. Twenty to 60 percent of the flat was covered by algae of the genera *Enteromorpha*, *Ulva*, and *Chaetomorpha* during July and August. Scattered salt marshes and rocky shoreline surrounded the flats (Appendix I). This area was probably the most important feeding site in Cobscook Bay for semipalmated sandpipers (65,000), semipalmated plovers (300), and black-bellied plovers (25). The high count for semipalmated sandpipers was on August 11 on the flats at low tide after dark and likely indicates roosting rather than feeding by the more common number of 2000-6000 shorebirds.

Virtually all shorebirds from this flat roosted on the sand beach in Johnson's cove or along the high-tide line near Mathew's Island.

Johnson's Cove

This was an important roosting area on a sand beach for semipalmated sandpipers (6500) and semipalmated plovers (300).

Half Moon Cove

Most of the cove consisted of flats varying from mud-sand to liquid mud. Rocks and boulders were scattered throughout the area, and gravel and boulder flats predominated in the lower part of the cove. The periphery was composed of rocky shorelines, a man-made causeway, and small salt marshes. This was an important feeding area for almost all species of shorebirds because of the diversity of habitats available at low tide. Lower Half Moon Cove was important for semipalmated sandpipers (1200) and semipalmated plovers (150). Greater and lesser yellowlegs and black-bellied plovers occasionally used the area for feeding. Upper Half Moon Cove was important for feeding semipalmated sandpipers (2800), black-bellied plovers (10), and least sandpipers. Semipalmated plovers regularly fed in the area, and lesser yellowlegs occasionally foraged in the area.

Shorebirds using Half Moon Cove roost in numerous locations, including Gleason Cove, Carlow Island, rocky shorelines around Half Moon Cove, and along the causeway.

Carlow Island

This area was used by feeding semipalmated sandpipers (3200) and semipalmated plovers (280). Ruddy turnstones, greater and lesser yellowlegs, and black-bellied plovers were also observed regularly in the area. The area also included a series of semi-permanent roosts (100-500 birds) along the causeway and the rocky shorelines. The abundance and composition of roosting flocks was similar to that of feeding shorebirds.

Gleason Cove

This area included a gravel bar near the boat launch that was used by semipalmated sandpipers (2000).

Birch Point

This area was used consistently by 300-500 feeding semipalmated and least sandpipers. It also included a gravel beach that was used for roosting by semipalmated sandpipers (250).

Goose Island

This area was used as a roost by semipalmated sandpipers (200).

East Bay

That was used regularly by feeding greater and lesser yellowlegs and semipalmated sandpipers.

Sipp Bay

The bay varied from rocky mudflats to salt marsh and rocky shoreline on the periphery. This was an important mid-bay feeding area for semipalmated sandpipers (450) and greater and lesser yellowlegs (19). Black-bellied plovers were observed feeding here occasionally in late August. Shorebirds were never observed roosting in the area.

Pennamaquan River

This was an important feeding area for greater and lesser yellowlegs (46) during July and August.

Hersey Cove

This was a feeding area used regularly by 200-300 semipalmated and least sandpipers and lesser yellowlegs.

Hardscrabble River

Greater and lesser yellowlegs (18) fed here regularly.

Denny's River

This was used regularly by low numbers (8) of greater and lesser yellowlegs. The area was comprised of mud flats with scattered mussel beds.

Hobart Stream

This was also used regularly by 5-20 greater and lesser yellowlegs.

Edmunds

This area included a mud flat used by feeding semipalmated sandpipers (180) and greater and lesser yellowlegs (7) especially during the peak of migration.

Whiting Bay

This was the most important inner-bay feeding area for semipalmated sandpipers (350), yellowlegs (32), short-billed dowitchers (25), semipalmated plovers (50), and black-bellied plovers (25). An American golden plover was seen at this area. The substrate of this area was sawdust covered by mud.

Nutter Cove

This cove includes mud flats with rocky shorelines and salt marshes present. Few shorebirds ever used this area for feeding. No roosting was observed in the area.

Federal Harbor

Semipalmated sandpipers and yellowlegs used this area for feeding only occasionally.

Hallowell Island

This area was used as a roost for semipalmated sandpipers (150) feeding in the Edmunds area.

Western Passage and Head Harbor Passage

These open-water areas were important feeding and roosting areas for northern phalaropes (500,000). Peak numbers were in mid-August.

SPECIES DESCRIPTIONS

Twenty-one species of migratory shorebirds were observed using the Cobscook Bay area in 1979. This section describes the seasonal abundance, phenological patterns, and general patterns of habitat utilization of the most common species.

Semipalmated Sandpipers

Semipalmated sandpipers arrived in the Cobscook Bay area on their southward migration in mid-July. Highest numbers were recorded in mid-August (Table 2), and populations declined thereafter. Mature birds arrived first in July, while juvenile birds were first seen in Cobscook Bay in mid-August. The staggered migration of juvenile and adult semipalmated sandpipers resulted in a noticeable bimodel peak in sandpiper abundance in some areas.

The semipalmated sandpiper is one of the most common migrant shorebirds in the Cobscook Bay area. The maximum number of these shorebirds recorded in our study was 65,000 at Carryingplace Cove in mid-July. Semipalmated sandpipers preferred mud and sand/mud flats for feeding. Roosting areas were less specific, as rocky shorelines, gravel bars, sand beaches, blueberry barrens, and baseball fields were all used as roosts in Cobscook Bay. Low to moderate human activity seems to have little effect on semipalmated sandpiper roosting and feeding areas. Roosts were temporarily deserted if disturbance was excessive.

Tidal action dominates feeding behavior of semipalmated sandpipers in Cobscook Bay. Typically they are the first birds to arrive at feeding areas

Table 2. Maximum counts of peeps (semipalmated sandpiper, least sandpiper, western sandpiper) in Cobscook Bay, Maine per 10-day period, 1979. Semipalmated sandpipers predominated.

AREA	DATE									TOTAL
	JULY			AUGUST			SEPTEMBER			
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	
Upper Half Moon Cove	0	485	665	1050	2800	1500	-	21	0	6521
Pleasant Point	-	-	900	900	-	2000	-	500	41	4341
Carlow Island	-	-	-	3200	-	2450	-	3000	0	8650
Carryingplace Cove (outer bay)	-	-	4000	3300	65,000	4500	2500	175	-	79,475
Johnson Cove	-	-	-	3000	-	6500	-	1500	0	11,000
Broad Cove	-	-	1420	1100	0	-	-	175	-	2695
Sipp Bay	-	1	250	300	-	450	-	-	-	1001
Sutter Cove	-	0	5	-	170	-	-	-	-	175
Long Cove	-	0	0	0	-	-	-	-	-	0
Carryingplace Cove (inner)	-	0	0	-	0	-	-	-	-	0
Whiting Bay	11	12	173	350	-	200	-	0	-	746
Dennys River	0	0	0	-	12	-	-	-	-	12
Edmunds Flats	0	0	180	0	-	-	-	-	-	180
Lubec flats	-	250	2500	1300	-	800	5	-	-	4955
Lubec gravel bar	-	-	4500	-	1800	-	-	-	-	6300
Lubec center beach	-	-	4900	4100	4000	0	-	-	-	13,000
Lubec medical center	0	-	3300	5000	2000	3500	-	75	35	13,910
Town of Lubec	-	-	1300	0	-	4000	-	2	0	5302
TOTAL	11	748	24,093	23,600	75,782	25,900	2505	5,448	76	158.263

as the tide begins to fall. On well drained flats, birds generally feed in dense aggregations along the receding tide line and follow the tide line back in. On flats with poor drainage or algal coverage, birds disperse over the flat until the rising tide forces them to higher ground.

Least Sandpipers

Least sandpipers were common shorebird migrants in Cobscook Bay although not as numerous as semipalmated sandpipers. Least sandpipers first arrived in early July and were commonly recorded throughout August and September. Because of the difficulty in differentiating least and semipalmated sandpipers at a distance, they were grouped collectively as "peeps" (Table 2).

Least sandpipers were seen most often in small flocks in salt marshes and coastal freshwater habitats. However, they often were found feeding on mud flats with other shorebirds.

White-rumped Sandpipers

White-rumped sandpipers were uncommon fall migrants in eastern Maine. Birds were first sited in the Lubec area in mid-August. Concentrations of 5-10 birds were observed in Lubec in September. Like other sandpipers, white-rumps were observed feeding on mud and sand/mud flats.

Sanderlings

Sanderlings were common autumn migrants in the Lubec area from mid-July through September (Table 3). Three-hundred individuals were seen in Lubec in late July. Nearly all sanderlings in the Lubec area were observed feeding and roosting on a sand beach near the Lubec Medical center.

Short-billed Dowitchers

Short-billed dowitchers were common migrants in Cobscook Bay during the

Table 3. Maximum counts of sanderling in Cobscook Bay per 10-day period 1979.

AREA	DATE									TOTAL
	JULY			AUGUST			SEPTEMBER			
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	
Upper Half Moon Cove	0	0	0	0	0	0	-	0	0	0
Carryingplace Cove (outer bay)	-	-	0	0	-	0	0	1	0	1
Broad Cove	-	-	0	0	0	-	-	0	-	0
Sipp Bay	-	0	0	0	-	0	-	-	-	0
Whiting Bay	0	0	0	0	-	0	-	0	-	0
Lubec flats	-	0	3	0	-	20	0	2	-	25
Lubec gravel bar	-	-	0	-	0	-	-	-	-	0
Lubec center beach	-	-	100	70	1	0	-	-	-	171
Lubec medical center	0	-	15	0	50	75	-	0	0	140
Town of Lubec	-	-	5	0	-	300	-	3	0	308
TOTAL	0	0	123	70	51	395	0	6	0	645

fall migration. Individuals and small groups of birds were seen on many of the mudflats in the Cobscook - Lubec area starting in mid-July. Twenty dowitchers were observed on the Whiting study area for about 2 weeks in late July and early August. Further south in Machias Bay, over 1000 short-billed dowitchers were observed from mid-July through early August.

Dowitchers usually foraged on mud flats beyond the tide line in several cm of water. Roosting areas were usually located in areas of low human disturbance.

Knots

Knots were rare fall migrants in Cobscook Bay during fall migration. Five birds were seen in the Lubec area in early August. Knots shared the same feeding and roosting habitats as sanderling near the Lubec Medical Center.

Greater Yellowlegs

Greater yellowlegs were the first migratory shorebirds to arrive in Cobscook Bay area in early July and were present through late August. Peak numbers occurred in Cobscook Bay in late July (Table 4). Greater yellowlegs were most frequently seen in association with lesser yellowlegs and short-billed dowitchers.

Greater yellowlegs preferred salt marshes and mud flats at the mouths of the larger streams and rivers in Cobscook Bay. Here, food taken is apparently sand shrimp, amphipods, and small fish. Areas that consistently attracted feeding greater yellowlegs include the outlets of Dennys River, Whiting River, Hobart Stream, Hardscrabble River, Pennamaquan River, and Smith Brook.

Table 4. Maximum counts of yellowlegs (greater and lesser) in Cobscook Bay, Maine per 10-day period 1979.

AREA	JULY 1-10	JULY 11-20	JULY 21-30	AUGUST 1-10	AUGUST 11-20	AUGUST 21-31	SEPTEMBER 1-10	SEPTEMBER 11-20	SEPTEMBER 21-30	TOTAL
Upper Half Moon Cove	0	0	0	0	0	1	-	2	0	3
Pleasant Point	-	-	0	4	-	0	0	1	0	
Carlow Island	-	-	-	0	-	6	-	0	0	
Carryingplace Cove (outer bay)	-	-	2	0	-	3	0	0	-	5
Johnson Cove	-	-	-	0	-	0	-	0	0	
Broad Cove	-	-	0	0	0	-	-	2	-	2
Sipp Bay	-	11	19	6	-	8	-	-	-	44
Nutter Cove	-	2	1	-	6	-	-	-	-	
Long Cove	-	0	0	0	-	-	-	-	-	
Whiting Bay	27	19	32	10	-	17	-	0	-	105
Denny's River	4	3	8	-	0	-	-	-	-	
Edmunds flats	0	0	7	0	-	-	-	-	-	
Lubec flats	-	1	2	0	-	5	0	4	-	
Lubec gravel bar	-	-	0	-	4	-	-	-	-	
Lubec center beach	-	-	0	0	0	0	-	-	-	
Lubec medical center	0	-	0	0	0	0	-	1	0	1
Town of Lubec	-	-	0	0	-	0	-	0	0	
TOTAL	31	36	71	20	10	40	0	10	0	160

Lesser Yellowlegs

Lesser yellowlegs appeared about 10 days later than great yellowlegs in Cobscook Bay. By late July lesser yellowlegs were just as abundant as greater yellowlegs (Table 4). Peak numbers occurred in Cobscook Bay in late July. By early September most birds depart.

As mentioned earlier, greater and lesser yellowlegs shared essentially the same habitats and have similar foraging behavior. Observation of roosting yellowlegs in Cobscook Bay were rare. Apparently they roosted in salt marshes adjacent to feeding areas.

Willets

Willets were rare migrants in eastern Maine. One individual was observed on the Lubec flats after a storm in mid-September. Willets may nest in southern Maine.

Ruddy Turnstones

Ruddy Turnstones were common migrants in Cobscook Bay. Turnstones first appeared in late July and migration peaked in mid-August when 125 birds were sighted on the Lubec gravel bar roost (Table 5). Turnstones preferred rocky shoreline and gravel beaches for feeding habitat. Usually several birds foraged together and large aggregations of feeding or roosting birds were rare.

Whimbrels

Whimbrels were rare migrants in Cobscook Bay during fall migration. Two birds were observed for several days on the Lubec flats in late July. Sightings of small flocks of whimbrels in blueberry barrens in the Cobscook Bay area have been reported. Whimbrels may prefer these habitats for feeding over marine habitats. In southern Maine and Massachusetts whimbrels frequent salt marshes with large populations of fiddler crabs (Uca sp.), their favored prey.

Table 5. Maximum counts of ruddy turnstone in Cobscook Bay, Maine per 10-day period 1979.

AREA	DATE									TOTAL
	JULY			AUGUST			SEPTEMBER			
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	
Pleasant Point	-	-	0	3	-	1	0	1	0	
Broad Cove	-	-	0	2	0	-	-	1	-	3
Lubec flats	-	0	3	0	-	0	0	0	-	3
Lubec gravel bar	-	-	0	-	125	-	-	-	-	125
Lubec center beach	-	-	1	6	4	0	-	-	-	11
Lubec medical center	0	-	0	0	5	0	-	-	-	5
Town of Lubec	-	-	6	0	-	14	-	2	0	22
TOTAL	0	0	10	11	134	15	0	4	0	169

Semipalmated Plover

Semipalmated plovers were first seen in mid-July. Their numbers steadily increased until mid-August (Table 6). Some birds were still seen in the area in late September. Semipalmated plovers were abundant in Cobscook Bay with populations building up to several thousand birds in some areas. The U.S. Fish and Wildlife Service identified the eastern Maine coast as the most critical habitat for this species in the eastern United States.

Semipalmated plovers were usually seen feeding in mud and sand flats with semipalmated sandpipers. However, feeding strategies were entirely different between these species. Plovers are visual feeders while sandpipers are primarily tactile feeders. Plovers stand and watch for food, run several steps, stand, then run again. Favored prey of plovers seemed to be polychaete worms. Plovers dispersed over the flats and rarely followed the tide line as sandpipers. Once dispersed, plovers were territorial exhibiting aggressive behavior towards any shorebird that invaded their feeding territory.

Juvenile semipalmated plovers were first noted in Cobscook Bay in mid-August. Soon thereafter, adult birds began to molt adding to the difficulty of separating the age groups.

The largest semipalmated plover roosts were located near the Lubec Medical Center. Up to 1100 birds were observed roosting in this location. Like sandpipers, semipalmated plovers were reasonably tolerant of human activity near roosting sites.

Black-bellied Plover

Black-bellied plovers were common fall migrants. Birds were first seen in late July and increased steadily until late August (Table 7). Over 2000 birds were sighted in mid-August on the gravel-bar roost in Lubec. No birds were seen in the area after mid-September.

Table 6. Maximum counts of semipalmated plover in Cobscook Bay, Maine per 10-day period 1979.

AREA	DATE									TOTAL
	JULY			AUGUST			SEPTEMBER			
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	
Upper Half Moon Cove	0	3	9	3	5	5	-	4	0	29
Pleasant Point	-	-	2	25	-	125	-	59	11	322
Carlow Island	-	-	-	10	-	280	-	0	0	290
Carryingplace Cove (outer bay)	-	-	0	300	-	12	0	3	-	315
Johnson Cove	-	-	-	300	-	250	-	45	0	595
Broad Cove	-	-	265	50	0	-	-	31	-	346
Sipp Bay	-	0	0	5	-	4	-	-	-	9
Nutter Cove	-	0	0	-	0	-	-	-	-	0
Long Cove	-	0	0	0	-	-	-	-	-	0
Carryingplace Cove (inner bay)	-	0	0	-	0	-	-	-	-	0
Whiting Bay	0	0	5	10	-	50	-	0	-	65
Dennys River	0	0	0	-	0	-	-	-	-	0
Edmunds flats	0	0	0	0	-	-	-	-	-	0
Lubec flats	-	0	30	0	-	200	7	30	-	267
Lubec gravel bar	-	-	0	-	150	-	-	-	-	150
Lubec center beach	-	-	450	303	423	0	-	-	-	1176
Lubec medical center	0	-	130	200	350	1100	-	25	5	1810
Town of Lubec	-	-	123	0	-	750	-	15	0	988
TOTAL	0	3	1012	1206	928	2816	7	222	16	6162

Table 7. Maximum counts of black-bellied plover in Cobscook Bay, Maine per 10-day period 1979.

AREA	DATE: JULY 1-10	JULY 11-20	JULY 21-30	AUGUST 1-10	AUGUST 11-20	AUGUST 21-31	SEPTEMBER 1-10	SEPTEMBER 11-20	SEPTEMBER 21-30	TOTAL
Upper Half Moon Cove	0	0	0	0	2	10	-	0	0	12
Pleasant Point	-	-	0	1	-	0	0	9	0	10
Carlow Island	-	-	-	0	-	6	-	0	0	6
Carryingplace Cove (outer bay)	-	-	3	0	-	25	0	5	-	33
Johnson Cove	-	-	-	0	-	0	-	0	0	0
Broad Cove	-	-	0	0	0	-	-	73	-	73
Sipp Bay	-	0	0	3	-	20	-	-	-	23
Nutter Cove	-	0	0	-	0	-	-	-	-	0
Long Cove	-	0	0	0	-	-	-	-	-	0
Caryingplace Cove (inner bay)	-	0	0	-	0	-	-	-	-	0
Whiting Bay	0	0	0	0	-	25	-	0	-	25
Dennys River	0	0	0	-	1	-	-	-	-	1
Edmunds flats	0	0	0	0	-	-	-	-	-	0
Lubec flats	-	0	1	7	-	200	55	20	-	283
Lubec gravel bar	-	-	0	-	2000	-	-	-	-	2000
Lubec center beach	-	-	0	0	2	0	-	-	-	2
Lubec medical center	0	-	0	0	61	23	-	5	0	89
Town of Lubec	-	-	0	0	-	0	-	20	0	20
TOTAL			4	11	2066	369	55	132	0	2577

Black-bellied plovers have less strict habitat requirements than semipalmated sandpipers. In Cobscook Bay the birds were usually seen feeding on mud flats, but they were occasionally seen feeding and roosting on mowed fields inland. Black-bellied plovers were easily disturbed by human disturbance on feeding and roosting sites. Roosting sites were usually in remote areas with little human disturbance. Like semipalmated sandpipers, black-bellied plovers are visual feeders, and birds were observed taking large polychaete worms, snails, and small clams.

American Golden Plovers

American golden plovers were rare migrants in the Cobscook Bay area. One individual was observed feeding on the Whiting mud flat in mid-September. Golden plovers are more commonly seen in inland plowed and mowed fields which accounts for their general absence in marine habitats.

Northern Phalaropes

Northern phalaropes were the most common shorebird in the Cobscook Bay area during fall migration (Table 8). Unlike most shorebirds, phalaropes are pelagic spending all of their time on the open water. Flocks of several hundred birds began to congregate (late July) in Western Passage between Eastport, Deer Island, and Campobello Island (New Brunswick). By late August approximately 500,000 birds in several flocks were reported in the area. Phalarope numbers dwindled soon after but some birds remained in the area until early October.

Phalaropes feeding concentrations were highest in the tidal slicks on an outgoing tide. Here they feed exclusively on marine zooplankton brought to the surface by the currents. Phalaropes were observed to repeatedly fly to the head of a tidal slick and drift with the current for up to 1 km. This foraging behavior resulted in a continuous flight of birds flying to the head

Table 8. Maximum counts of northern phalarope in Head Harbor Passage per 10-day period 1979.

AREA	DATE									TOTAL
	JULY			AUGUST			SEPTEMBER			
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	
Wilsons Beach	-	-	-	-	350,000	300,000	-	200	1500	651,700
Deer Island Point, Eastport Ferry	-	-	-	-	160,000	1,000,000	15,000	6300	1100	1,182,400
TOTAL	-	-			510,000	1,300,000	15,000	6500	2600	1,834,100

of a slick during an outgoing tide. Some of these flights lasted for several hours. Little is known of the foraging behavior, food preference, activity and actual numbers of these birds during their autumn staging and migration off Eastport.

INVERTEBRATE ABUNDANCE AND HABITAT SELECTION

Staging migratory shorebirds tend to form dense multi-specific aggregations in prime feeding areas. Most shorebirds utilize a variety of marine habitats that differ as to substrate and invertebrate fauna, however, all habitats utilized by shorebirds are similar in several important respects. First, vertical diversity in marine littoral habitats is limited to the substrate itself. Vertical diversity below the substrate results from a stratification of invertebrate food items. Tidal action allows different assemblages of organisms to utilize the same habitat without coming into direct contact. Second, horizontal diversity in marine littoral habitats results from an intermixture of different substrates, length of time the area has been above water and how wet the area has remained, resulting in highly clumped aggregations of invertebrates.

Shorebirds acting as predators on intertidal invertebrates can respond to spatial variation in prey density in 3 fundamental ways: 1) shorebird numbers increase in areas of high prey density, 2) shorebirds spend more time in areas of high prey density, and 3) shorebird feeding rate increases in areas of high prey density. The purpose of this section is to relate the distribution and abundance of invertebrate prey species. Responses 2 and 3 will be investigated in further studies during the spring and fall shorebird migration in 1980.

Carryingplace Cove:

Abundance indices for semipalmated sandpipers and black-bellied plover were compared with invertebrate densities and distributions in Carryingplace Cove (Tables 9 and 10). Oligochaetes, Hydrobia sp., and Littorina littorea were the most abundant invertebrate organisms in Carryingplace Cove. Oligochaetes and Hydrobia sp. generally increase in density from high to low intertidal, but Littorina was more numerous in the upper intertidal. Semipalmated sandpiper distribution was significantly correlated with nemertea abundance on the study plots. However, these invertebrates were not observed to be taken by semipalmated sandpipers. Black-bellied plover distribution was weakly correlated (P=.1) with Hydrobia densities, a confirmed prey species. Weak correlations with Clymanella torquata and Littorina littorea abundance also may suggest some importance of these invertebrates in black-bellied plover diet.

Half Moon Cove

Abundance indices for semipalmated sandpipers and semipalmated plovers were compared with invertebrate densities and distributions (Tables 9 and 11). Oligochaetes, Hydrobia sp., Clymanella torquata, and Corophium volutator were the most abundant invertebrate species in Half Moon Cove. Oligochaetes and Hydrobia sp. were most abundant in the mid-intertidal region, Clymanella torquota was most abundant in the mid to low intertidal region, and Corophium volutator was found in high densities in the sandy high intertidal. Semipalmated sandpiper distribution was correlated with Mya arenaria, Clymanella torquata, Spio filicornis, Streblospio benedicti, insect and Corophium volutator densities on the study plots. Although Clymanella, Spio, and Streblospio were not observed to be taken by sandpipers they may well be important prey for these birds. Mya was probably not a food of semipalmated sandpipers. The correlation between semipalmated sandpipers and Corophium

Table 9. Correlation between semipalmated sandpiper abundance index and invertebrate density in Cobscook Bay.

INVERTEBRATE	SPEARMAN CORRELATION COEFFICIENT PROBABILITY LEVEL1/			
	Carryingplace Cove (N=20)	Whiting (N=13)	Half Moon Cove (N=16)	Sipp Bay (N=12)
Phylum Rhynchocoela	.6359 .003 1/	-	-.3403 .197	.5901 .043 1/
Phylum Aschelmenthes	.4318 .057	.2086 .498	-.3806 .146	.2922 .357
Littorina littorea	-.4197 .066	-	.2379 .3749	.2526 .428
Hydrobia sp.	-.1713 .470	-	-	.5499 .064
Lunatia heros	-	-	.0501 .854	-
Macoma balthica	.0395 .869	-	-.0603 .824	.3592 .251
Mya arenaria	.1848 .453	-	.4972 .050 1/	.4551 .137
Skeneopsis planorbis	.2259 .338	-	-	-
Nereis virens 2/	.2853 .283	.4155 .158	-	.6797 .015 1/
Nereis pelagica 2/	-	.5536 .050 1/	-	
Phyllodoce mucosa	-	-	-	-.4639 .129
Spio filicornis	-	.0324 .916	-.5423 .030 1/	.0513 .874
Streblospio benedicti	-	-	-.5024 .047 1/	-.1882 .558
Clymanella torquata	-.0184 .733	-	-.4317 .095	-.4081 .188
Fabricia sabella	.3420 .140	-	-.02789 .918	.1078 .739

Table 9. continued

INVERTEBRATE	Carryingplace Cove	Whiting	Half Moon Cove	Sipp Bay
Orbinia sp.	-	-	-.2379 .375	-
Class Oligochaeta 2/	.3381 .145	.2041 .504	-.3519 .181	-.2737 .389
Corophium volutator 2/	-	.2972 .324	.5809 .018 1/	-
Class Insecta	-.0309 .897	-	-.5290 .035 1/	-

1/ Probability less than 0.05 indicates significant relationship.

2/ Indicates invertebrates known to be eaten by semipalmated sandpipers in Cobscook Bay.

Table 10. Correlation between black-bellied plover abundance index and invertebrate density in Carryingplace Cove.

INVERTEBRATE	SPEARMAN CORRELATION COEFFICIENT PROBABILITY LEVEL[1] Carryingplace Cove (N=20)
Phylum Rhynchocoela	-.0916 .701
Phylum Aschelmenthes	-.2825 .228
Littorina littorea [2]	.2532 .282
Hydrobia sp. [2]	.3767 .102
Macoma balthica [2]	.0387 .871
Mya arenaria	-.1596 .502
Skeneopsis planorbis	.0905 .704
Fabricia sabella	-.0636 .790
Clymanella torquata	.2647 .259
Class Oligochaeta	-.1873 .429
Class Insecta	-.2471 .294

1/ Probability less than 0.05 indicates significant relationship.

2/ Invertebrates known to be eaten by black-bellied plovers.

corresponds with their previously described feeding behavior in this area. Semipalmated plover distribution was not correlated with distribution and abundance of any invertebrate species. There was a weak correlation with *Littorina littorea*. Utilization of *Littorina* as a prey species was not observed.

Sipp Bay

Semipalmated sandpiper abundance index was compared with invertebrate densities and distribution in Sipp Bay (Table 9). Here sandpiper abundance was correlated with nemertea, *Hydrobia* sp., and *Nereis virens* densities on the study plots. Oligochaetes were the single, most abundant invertebrates on the Sipp Bay plots but were not highly correlated with sandpiper distribution.

Whiting Bay

Semipalmated sandpipers, semipalmated plovers, and yellowlegs abundance indices were compared with invertebrate densities on study plots (Tables 9, 11 and 12). Semipalmated sandpiper distribution was correlated with *Nereis pelagica* distribution and abundance and weakly correlated with *Nereis virens* distribution. Semipalmated plovers also had weak correlations with these 2 species. Yellowlegs distribution was also weakly correlated to *Nereis pelagica* abundance and distribution. *Corophium volutator* and oligochaetes were the most abundant invertebrate organisms on the flat but were not correlated with shorebird distribution.

Occasionally shorebird distributions on study areas were correlated with the abundance and distribution of confirmed prey organisms. For example, in the Half Moon Cove study area semipalmated feeding behavior associated with *Corophium* distribution was confirmed with the Spearmann correlation values. However, a suspected major prey species, oligochaetes, was not correlated with

Table 11. Correlation between semipalmated plover abundance index and invertebrate density in Cobscook Bay.

INVERTEBRATE	SPEARMAN CORRELATION COEFFICIENT PROBABILITY LEVEL[1/]	
	Half Moon Cove (N=16)	Whiting (N=13)
Phylum Rhynchocoela	-.2440 .363	-
Phylum Aschelmenthes	-.2060 .444	-
Littorina littorea	-.3857 .140	-
Lunatia heros	.0015 .996	-
Hydrobia sp.	.0077 .998	-
Macoma balthica	.0375 .891	-
Mya arenaria	.0697 .798	-
Nereis virens [2/]	.2272 .398	.3668 .218
Nereis pelagica	-	.4648 .110
Clymanella torquata	-	.0563 .840
Spio filicornis	.1824 .551	.0066 .981
Streblospio benedicti	.0132 .962	-
Orbinia sp.	.0781 .774	-
Fabricia sabella	.2135 .427	-
Class Oligochaeta	-.3247 .220	.4260 .147

Table 11. continued

INVERTEBRATES	Half Moon Cove (N=16)	Whiting (N=13)
Corophium volutator	.3275 .216	.1516 .611
Class Insecta	.2135 .427	-

1/Probability level less than 0.05 indicates significant relationship.

2/Indicates invertebrates known to be eaten by semipalmated plovers in Cobscook Bay.

Table 12. Correlation between yellowleg abundance index and invertebrate density in Whiting Bay.

INVERTEBRATE	SPEARMAN CORRELATION COEFFICIENT PROBABILITY LEVEL[1/] Whiting
Phylum Rhynchocoela	.4184 .155
Nereis pelagica	.4703 .105
Nereis virens	.3341 .265
Spio filicornis	.0189 .951
Class Oligochaeta	.15505 .613
Corophium volutator	.0376 .903

[1/]Probability less than 0.05 indicates significant relationship.

semipalmated sandpiper distribution on any of the study areas. This may have been the result of few observations at each of the study areas or these invertebrates may have been so abundant over the study areas that the birds had no need to concentrate their feeding in very high oligochaete densities. Although the small polychaetes, Spio and Streblospio, were not observed being taken by shorebirds they were correlated with semipalmated sandpipers on some of the study areas. Further investigation is needed to confirm these species as a shorebird food resource.

Semipalmated plover distribution was rarely correlated with distribution and abundance of any invertebrate species. In Whiting Bay there was a weak correlation with plover distribution and distribution of Nereis polychaetes, a preferred prey species. Plover aggression towards conspecifies and other shorebird species prohibits them from aggregating in areas of high invertebrate densities. The same observations and conclusions were made of semipalmated sandpipers feeding dispersion in Carryingplace Cove.

SUMMARY AND CONCLUSIONS

This report summarizes a 4-month investigation of southward shorebird migration in Cobscook Bay and surrounding areas in 1979. Twenty-one species of shorebirds were recorded during the fall migratory period. Most of these birds stop along the Maine coast during their spring migration in May, nest on the arctic tundra, and return to coastal staging areas in late summer. Here they feed intensively on marine invertebrates to build up fat reserves. These fat reserves are used as fuel for a non-stop flight from Maine to wintering areas in South America. Northern phalaropes, semipalmated sandpipers, semipalmated plovers, and black-bellied plovers were the most abundant species in the Cobscook Bay area in 1979.

Fall shorebird migration began in early July and peaked in mid-August after which numbers of shorebirds in the area declined steadily. Intertidal mud flats in the Eastport area (Half Moon Cove, Carryingplace Cove, Broad Cove) and Lubec attracted the largest numbers of shorebirds and are the most critical shorebird habitats in the Cobscook Bay region. Northern phalaropes are pelagic birds and were common in the tidal slicks off Eastport. The inner and mid-bay regions of Cobscook Bay had extensive mud flats but attracted few shorebirds. Since invertebrates were not extensively sampled in the mid-bay region, it is not known if lack of prey was the cause of this absence of birds. It is suspected that a lack of suitable roosting areas in the proximity of these areas may detract from their value as shorebird staging areas. During peak shorebird migration, shorebird numbers increased on mid-bay and inner-bay mud flats. This influx of birds may have been the result of depletion of invertebrate prey resources in the Eastport area.

Roosting habitats are just as important as feeding habitats for migratory shorebird populations. Shorebird species differed somewhat in their choice of roosting sites, but in general, shorebirds roosts were located on gravel bars, islands, or beaches where there was a minimum of human and animal disturbance. Roosting sites had to remain above water during high tide.

Invertebrate sampling showed that marine oligochaete worms were by far the most abundant food organisms available to shorebirds. Corophium volutator (a small amphipod) was present in moderate densities in isolated areas and were extensively fed upon by sandpipers and plovers. Semipalmated plovers and black-bellied plovers were most common in areas of high Nereis (polychaete worm) densities. Occasionally shorebird distribution was correlated (Spearman correlation procedure) with the abundance and distribution of confirmed prey organisms. Lack of correlation in some areas was due to foraging strategies of the species and relatively small sample sizes at each of the study areas.

Loss of quality and quantity feeding and roosting habitat from tidal power development or oil refinery construction in Cobscook Bay would surely result in a decline of shorebirds using the area. Whether these birds could displace to nearby heavily-used staging areas such as Lubec and Machias Bay is unknown. Loss of invertebrate food resources could cause failure of birds to reach migratory wintering or nesting destinations. For northern phalaropes and black-bellied plovers, the Cobscook Bay area provides a unique staging habitat that could not be duplicated in other coastal areas. Major habitat alterations or degradation could have a deleterious effect on these species' populations. The area is also of extreme importance for semipalmated sandpipers and semipalmated plovers and all other shorebirds species that depend on the area for food and rest during migration. Loss or displacement of these populations in the Cobscook Bay area would result in severe alteration of predator-prey relationships and energy flow in the intertidal environment and detract from the general aesthetic value of the region.

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APPENDIX I

CORRECTED NATIONAL WETLAND INVENTORY MAPS FROM U.S. GEOLOGICAL SURVEY 1:62,500, 15-MINUTE QUADRANGLES INCLUDING COBSCOOK BAY

Only coastal wetland sites were field-checked and listed. The Lubec quadrangle was included, because it is known to contain sites important to shorebirds even though it is not part of Cobscook Bay proper. Coastal areas along the Grand Manan Channel in the West Lubec quadrangle were not field-checked because the area is open ocean and outside the study area. Wetland types are designated using the following abbreviations:

M = marine or E = estuarine

1 = intertidal or 2 = subtidal

UB = unconsolidated bottom

AB = aquatic bed

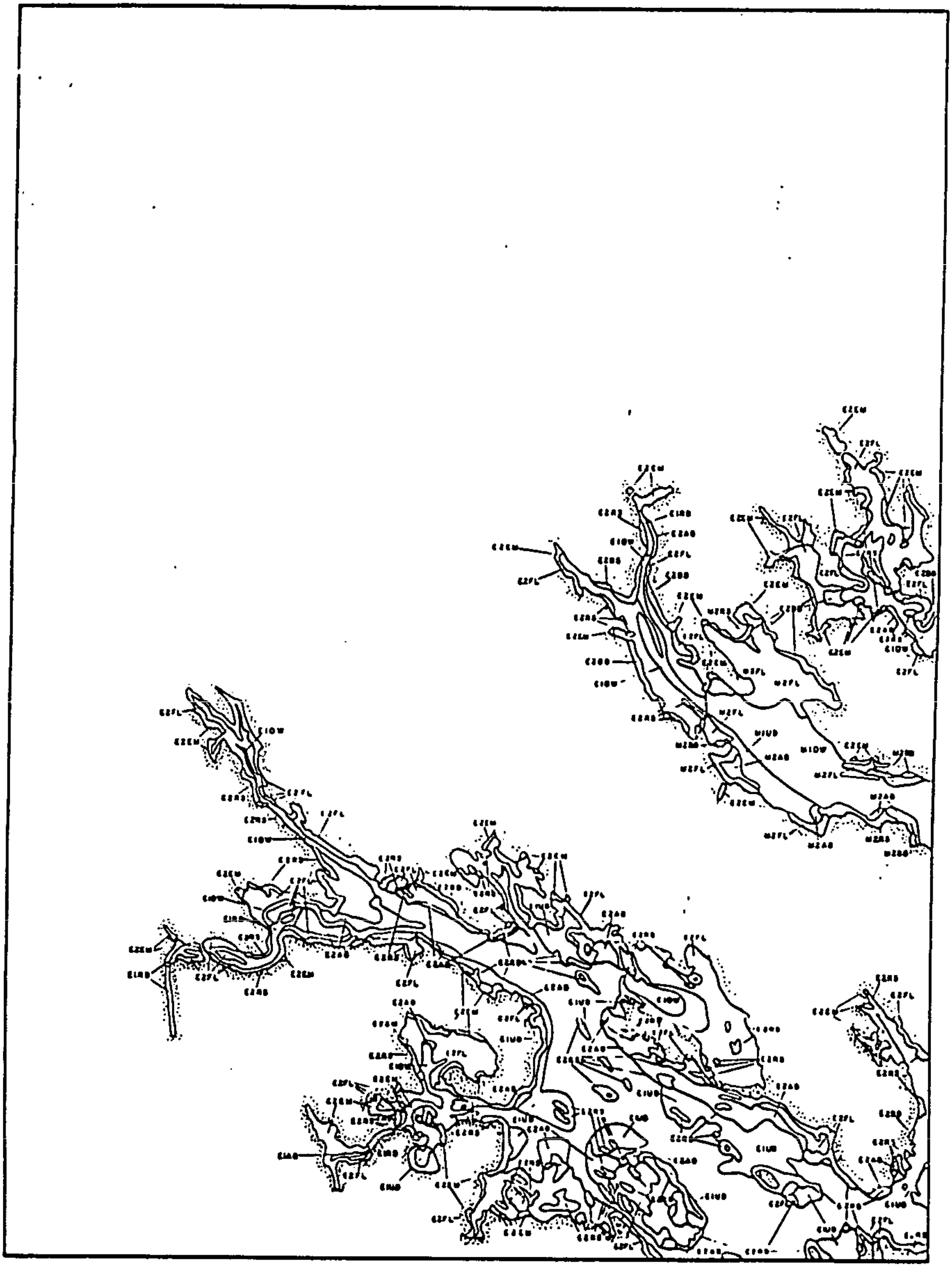
OW = open water

RS = rocky shore

FL = flat

EM = emergent

BB = beach bar



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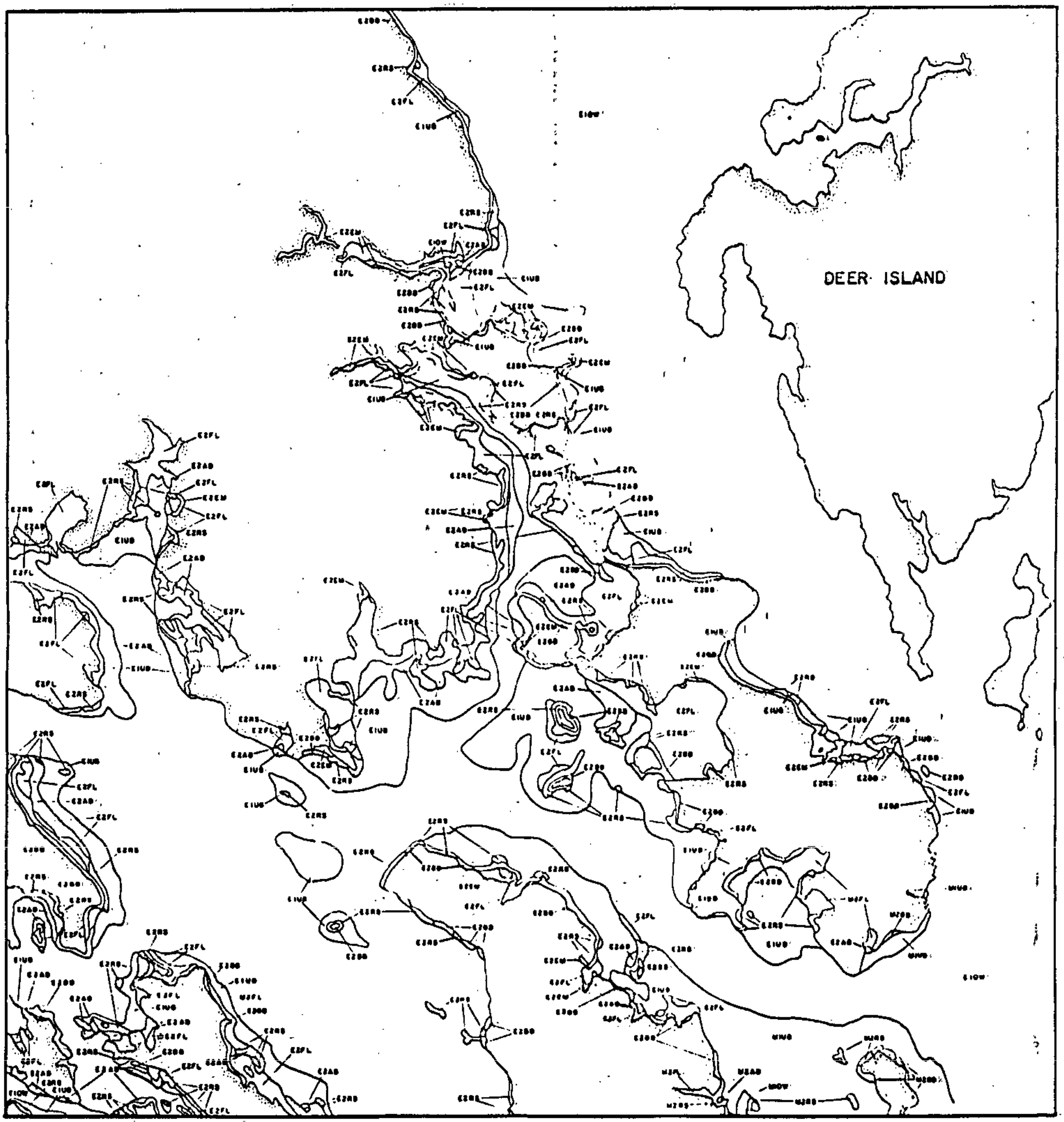

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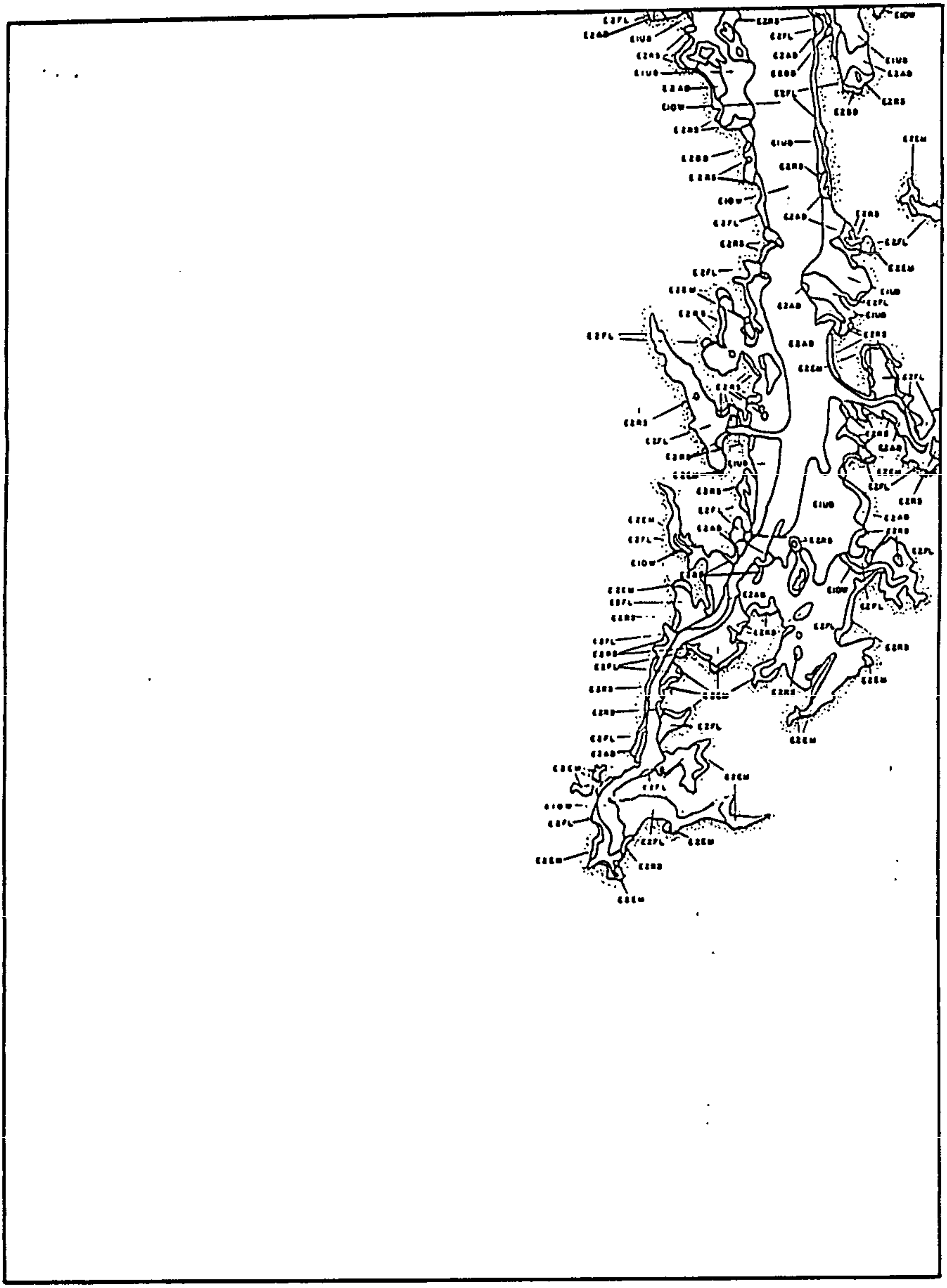

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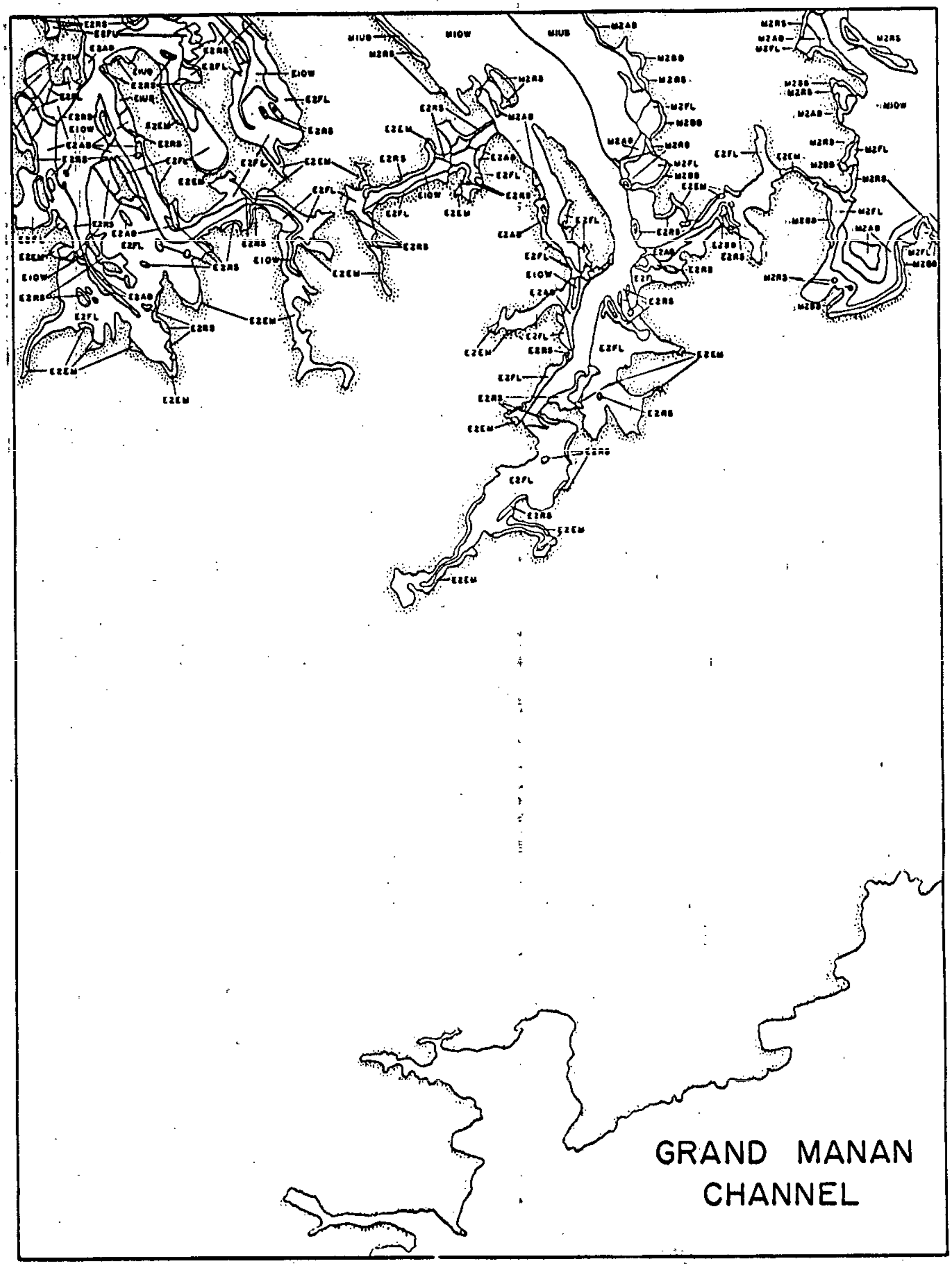

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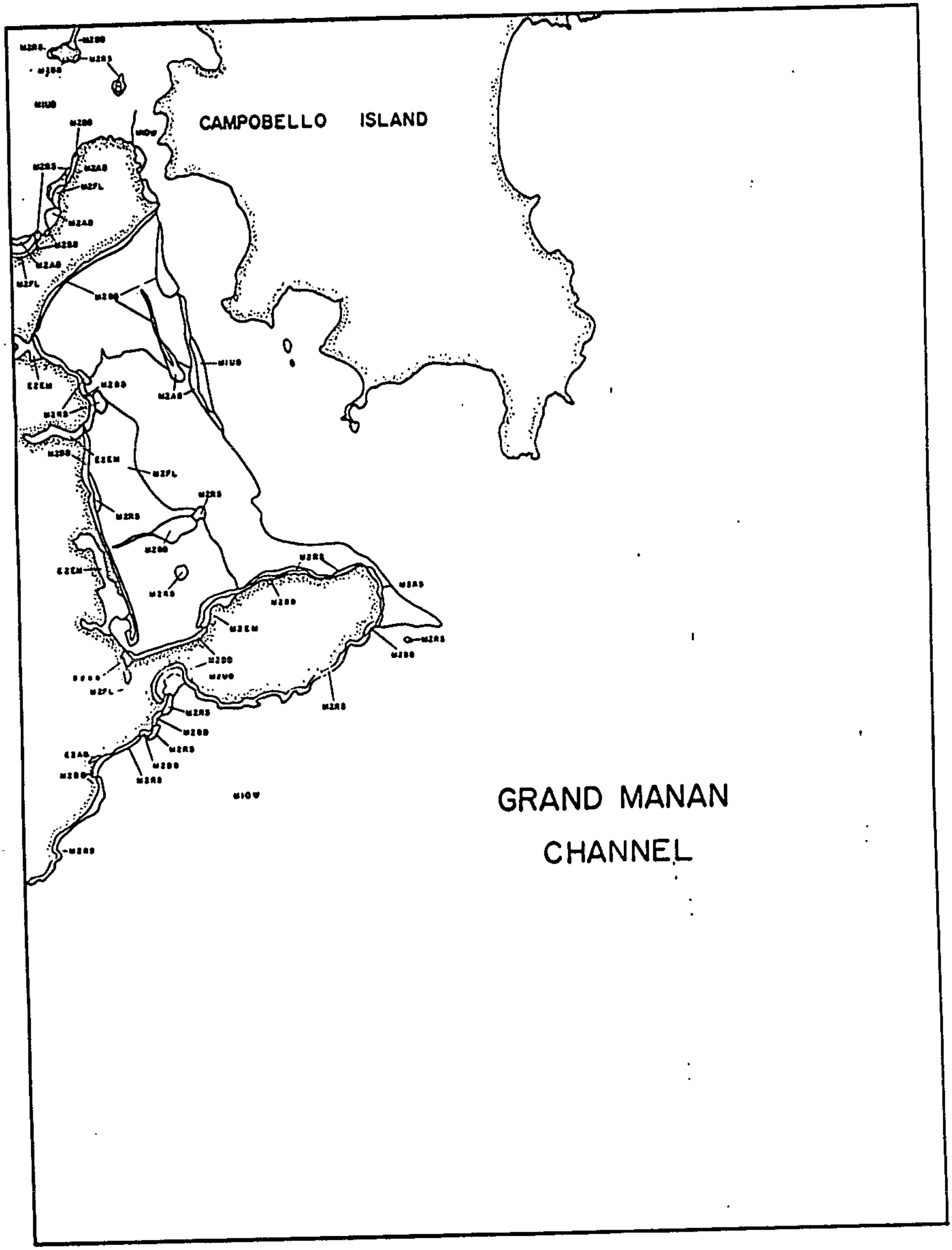

LUBEC

SOCIAL & CULTURAL RESOURCE APPENDIX

ENVIRONMENTAL BACKGROUND

Historic and Archaeological Resources:

The earliest known prehistoric sites in Passamaquoddy Bay date from about 1000 B.C. to the time of European contact. Other sites dating from as early as 9000 B.C. may have existed within the region, but rising sea levels and attendant erosion may have destroyed or obscured their remains. Also, it should be noted that most recorded sites were identified by presence of large shell heaps, which may not have been a feature of earlier sites.

Recorded prehistoric sites in Cobscook Bay reflect intensive use of marine food sources, primarily soft shell clams. Some hunting also appears to have been done, as deer and beaver remains are commonly found at the sites with moose, caribou, bear, and seal in lesser quantities. Pottery appears in the area at the beginning of this period (c. 1000 B.C.), but seems later to have decreased in use. Most tools recovered consist of projectile points of stone, and scraping and cutting implements of stone or made from beaver incisors.

Evidence of semi-subterranean oval or round dwellings about 12 ft. in diameter are evident at sites dating between 2000 and 800 years ago. They have fire hearths near the hut entrance and sleeping benches nearby. Finds of animals killed in winter demonstrate that the occupants of these houses lived on the coast during that season. The partly underground nature of these houses may reflect this winter settlement.

Toward the end of the prehistoric period there are indications of a worsening of climate, and deer population appears to have dropped considerably. Rising sea levels in the region also changed the location of productive clam beds. A shift to seasonal migration of people from the coast to inland areas may have been partly conditioned by these environmental changes.

At the time of European contact, the native inhabitants appear to have spent their summers on the coast and wintered inland. The reverse of the prehistoric pattern, this probably reflects adaptation to the European fur trade system, with trapping in the interior during winter and trade with the ships which arrived in summer.

The first archaeological studies in the Passamaquoddy Bay area were undertaken by G.F. Matthew in 1884, who observed the sites of semisubterranean dwellings on the New Brunswick side of the bay. No further work is reported until the 1950's when the R.S. Peabody Foundation of Andover, Massachusetts surveyed Cobscook Bay and part of

Passamaquoddy Bay. More recent research undertaken by the University of Maine from 1968 to the present has concentrated on the Canadian shore, but has proved the most rewarding in providing data on the regions inhabitants during the late prehistoric period.

Recorded prehistoric sites within Cobscook Bay occur primarily on relatively sheltered portions of the shoreline, often near estuaries. None of the four alternative project locations presently being considered have recorded prehistoric sites at their landward ends. However, as archaeological survey of the region is still incomplete, an archaeological reconnaissance of these areas will become necessary as project planning proceeds to further stages of study. As operation of the completed project would decrease tidal fluctuations, erosion of prehistoric coastal sites around the pool would be diminished.

Historic period land use at the Cobscook Bay coastline has been largely maritime in nature, though there have been repeated attempts since the early 19th century to mine various metallic ores at exposed cliff faces.

Nearly all of the alternative dam locations under consideration tie-in to rural area of coastline where historic resources appear unlikely to exist. The single exception is the Lubec end of the Dudley alternative, which occupies a commercial waterfront area. Historic structures or historic archaeological resources may exist in this area. If the Dudley alternative is pursued in further planning, the presence or absence of such resources will be determined and potential effects of construction activity considered in more detail.

The numerous coves and inlets of Cobscook Bay provided secluded rendezvous for smugglers between the French and New England colonies during the Revolutionary War and the War of 1812 periods. Fishermen also used the bay from an early date and their activity became a mainstay of the area's economy during the 19th century. The considerable tidal fluctuations and narrow channels of Cobscook Bay probably resulted in numerous wrecks. While wrecks within the alternative pool areas would remain unaffected by project construction and operation, any within the dam construction limits would be destroyed. Further research will be undertaken at the next stage of project planning to determine whether any historically significant wrecks are located within the proposed dam construction areas.

COBSCOOK BAY TIDAL POWER PROJECT

WATER QUALITY REPORT

PREPARED BY

HYDRAULICS AND WATER QUALITY SECTION
WATER CONTROL BRANCH
NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS

JUNE 1980

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COBSCOOK BAY TIDAL POWER PROJECT

WATER QUALITY

1. INTRODUCTION

a. Purpose - The intent of this chapter is to present a description of water quality conditions as they currently exist in Cobscook Bay and as they will likely exist if the proposed tidal power development is constructed. Consideration has also been given to recommended areas for further detailed study should the project survive economic tests and continue on in the planning process.

This report is based solely upon a literature review. No original analysis was conducted. Considerable information was available from international studies of the Passamaquoddy tidal power project, namely the scientific reports of the International Passamaquoddy Fisheries Board in 1956-59. Also, for the past several years, Suffolk University has operated a laboratory adjacent to Cobscook Bay in support of its summer environmental program. (In this program undergraduate students collect, report, and analyze data gathered on some environmental aspect of the bay.) The draft environmental impact statement for the proposed Pittston oil refinery as well as environmental reports for the proposed Canadian Fundy tidal power project were also utilized. A complete listing of references is included at the end of the chapter.

It was felt that a review of these data would provide an adequate picture of current and future conditions for this level of study. Working from this base a more detailed level of water quality investigation could be developed should the economic justification for this project change.

2. EXISTING CONDITIONS

a. General - This section on existing water quality conditions will begin with a discussion of the watersheds contributing fresh water to Cobscook Bay. A description of their drainage areas, available flow data, and water quality in terms of State classification are included. The discussion then turns to Cobscook Bay itself, first with a look at the hydrodynamic situation explained through a treatment of the normal tide ranges, volumetric exchange, and currents of the bay and general area. (Currents of the general area being included since project construction could affect these currents.) Water quality conditions are then assessed with an examination of State water quality classifications, suspended solids, temperature, salinity, and dissolved oxygen. A general discussion wraps up this section with an overview characterization of current water quality conditions.

b. Watersheds Contributing to Cobscook Bay

(1) Drainage Area - The area tributary to Cobscook Bay is indicated on Figure 1. The total area includes the watersheds of the Dennys, Pennamaquan, and Orange Rivers as well as numerous other small streams. The area also includes some islands and portions of the shoreline not directly associated with any stream system.

The surface area of each sub-estuary in Cobscook Bay (see Plate 1) at the mean high water (MHW) and mean low water (MLW), the drainage area of each sub-estuary at MHW, and the area of islands above MHW and MLW are shown in Table 1. Dennys Bay has the largest total watershed area followed by Whiting Bay and the Pennamaquan River Estuary. The total drainage area at the mouth of Cobscook Bay is 371.65 square miles.

The land surface of the watershed is composed of gently rolling lowlands with numerous lakes of varying sizes and a few higher hills along the divides between the watersheds. Most of the area is composed of undeveloped and cutover timberlands with a small percentage utilized for agricultural activities such as dairying, poultry, or blueberry crops. The most concentrated population is found in Eastport and Lubec.

The average annual precipitation is about 40 inches and is fairly well distributed throughout the year. In this coastal area annual snowfall is about 70 inches. Average monthly temperatures vary from between 60° and 67°F in July and August to between 10° and 20°F in January and February. Extreme temperatures range from a high of 102°F to a low of 41°F below zero.

(2) Discharge - Since October of 1955, the U.S. Geological Survey has maintained a continuous flow gaging station at Dennysville, Maine on the Dennys River. The 92.4 square mile drainage area produces an average annual discharge of 192 cfs or 28.2 inches of runoff per year. The maximum recorded discharge of 3,930 cfs occurred on April 29, 1973. The minimum, 8.4 cfs, was recorded 1 October 1957.

COBSCOOK BAY DRAINAGE AREA MAP

FIGURE 1

TABLE 1
PERTINENT DATA - COBSCOOK BAY, MAINE

Sub-Estuary	Surface Area(sq.mi)	Contributing Drainage Basin	Drainage Area(sq.mi)
Johnson Bay	2.68(2.03)	Local	2.09
		Islands	0.16(0.29)
		Total D.A.	2.25
South Bay	5.96(4.38)	MaysBrk.	2.25
		Local	10.68
		Islands	0.25(0.29)
		Total D.A.	13.18
Morrison Cove	0.50(0.13)	Local	0.48
		Islands	0.02(0.00)
		Total D.A.	0.50
Nutter Cove	0.28(0.04)	Local	0.30
		Islands	0.02(0.03)
		Total D.A.	0.32
Straight Bay	1.75(0.55)	Local	6.60
		Islands	0.10(0.02)
		Total D.A.	6.70
Raft Cove	0.15(0.07)	Local	0.16
		Total D.A.	0.16
Whiting Bay	4.10(2.08)	East Str.	17.63
		Means Brk.	0.71
		Crane Brk.	0.66
		Orange R.	34.91
		CraneMillBrk.	3.55
		BurntCoveBrk.	1.73
		Local	8.72
		Islands	0.04(0.05)
		Total D.A.	67.95
Dennys Bay	4.79(2.67)	Hobart Str.	18.10
		Dennys R.	129.71
		Meadow Brk.	3.39
		Wilson Str.	7.43
		Local	9.82
		Islands	0.25(0.09)
		Total D.A.	168.70
Subtotals	20.21(11.95)		259.76

TABLE I (Cont.)

Sub-Estuary	Surface Area(sq.mi)	Contributing Drainage Basin	Drainage Area(sq.mi)
Long Cove	0.11(0.03)	Local	0.84
		Total D.A.	0.84
Schooner Cove	0.21(0.11)	Local	0.28
		Island	0.00(0.01)
		Total D.A.	0.28
Pennamaquan R.	1.63(0.85)	Willow Brk.	1.74
		Crow Brk.	2.81
		Pennamaquan R.	44.73
		Local	4.46
		Islands	0.01(0.00)
		Total D.A.	53.75
Sipp Bay	0.79(0.08)	Sipp Brk.	2.30
		Local	3.31
		Total D.A.	5.61
East Bay	1.05(0.79)	Smelt Brk.	1.10
		Local	2.97
		Islands	0.01(0.00)
		Total D.A.	4.08
Bar Harbor	1.22(0.50)	Local	3.91
		Islands	0.06(0.00)
		Total D.A.	3.97
Carryingplace Cove	0.36(0.01)	Local	0.57
		Total D.A.	0.57
Broad Cove	0.45(0.32)	Local	0.48
		Total D.A.	0.48
Cobscook Bay Central	11.50(9.85)	Local	4.48
		Islands	0.30(0.49)
		Total D.A.	4.78
Subtotal	20.21(11.95)		259.76
Grand Total	37.53(24.49)		334.12

NOTES:
1) All values are taken at MHW except values in parenthesis which are at MLW.
2) Listings begin at Lubec and proceed clockwise around the bay.
3) All areas computed from current 7.5 or 15 minute quadrangles, as applicable.

Mean monthly flows for the Dennys River are shown in Table 2.

TABLE 2

MEAN MONTHLY FLOWS
DENNYS RIVER AT DENNYSVILLE, MAINE

Month	Discharge (cfs)	Month	Discharge (cfs)
January	190	July	83
February	195	August	58
March	246	September	69
April	442	October	111
May	284	November	190
June	147	December	226

All other watersheds contributing to Cobscook Bay are ungaged. Since the Dennys River watershed is the largest contributor to the bay it produces the largest single fresh water inflow.

(3) Water Quality - The State of Maine, Department of Environmental Protection (DEP) has established standards for the classification of fresh waters within the State. In Table 3, applicable standards are summarized from "Classification of Surface Waters," Department of Environmental Protection, State of Maine, October 1977.

TABLE 3

STATE OF MAINE WATER QUALITY STANDARDS FOR CLASSIFICATION OF FRESH WATERS

Class	Uses	Prohibitions	Criteria
A	1. Recreation, including bathing 2. Public water supplies after disinfection	1. Sludge deposits 2. Solid refuse 3. Floating solids such as oil, grease or scum. 4. Any matter which would impart color, turbidity, taste, or odor other than naturally occurring. 5. Any matter which alters the temperature or pH. 6. Any matter containing chemicals harmful or offensive to humans or harmful to animal or aquatic life. 7. Radioactive matter other than naturally occurring. 8. Discharge of sewage or other wastes except licensed discharges which may continue until practical alternatives exist. 9. Bank deposits of sewage or other wastes where transfer to water is likely.	1. D.O.- not less than 75% saturation or as naturally occurs. 2. Fecal coliform - not more than 20 per 100 milliliters.
B-1	1. Recreation, including water contact 2. Potable water supply after adequate treatment 3. Fish and wildlife habitat	1. Sludge deposits 2. Solid refuse 3. Floating solids such as oils, grease, or scum. 4. Any matter which would impart color, turbidity, taste or odor which would impair classification uses. 5. Any matter altering temperature and pH to render conditions harmful to fish or aquatic life. 6. Discharge causing pH outside 6.0 to 8.5 range. 7. Any matter containing chemicals harmful to humans, animals or aquatic life or adversely affecting class uses. 8. Radioactive matter above USPHS drinking water standards. 9. Any matter altering bottom fauna composition, adversely affecting physical and chemical nature of bottom material or interfering with fish propagation.	1. D.O. - not less than 75% saturation and never less than 5 ppm. 2. Fecal coliform - not more than 60 per 100 milliliters.

TABLE 3 (Cont.)

Class	Uses	Prohibitions	Criteria
		10. Disposal of sewage, industrial waste, or other wastes not treated for adequate removal of waste constituents. Treated wastes will not lower standards, alter class usages, be injurious to aquatic life or render such unfit for human consumption.	
B-2	1. Recreational purposes, including water contact 2. Industrial and potable water supplies after adequate treatment. 3. Fish and Wildlife habitat.	Same as Class B-1	1. D.O. - not less than 60% of saturation and never less than 5 ppm. 2. Fecal coliform - not to exceed 200 per 100 milliliters.

Based upon the above standards, streams within the study area have been classified by the State DEP. Quoting from the above mentioned source:

1. "Dennys River and its tributaries above the Highway Bridge on Route 1 in the town of Dennysville - Class A.

2. Dennys River, main stem, from tidewater to the Bridge at U.S. Highway No. 1 at Dennysville - Class B-2.

3. Orange River and its tributaries above the highway bridge on Route 1 - Class A.

4. Orange River, main stem, between tidewater and the highway bridge at U.S. Highway No. 1 in Whiting - Class B-2.

5. Pennamaquan River, main stem, between the crossing of the Eastport Branch of the Maine Central Railroad and tidewater - Class B-2.

6. All coastal streams, segments and tributaries thereof, not otherwise defined, above tidewater, entering the tidal waters of Washington County from the Washington-Hancock County line to and including those to the tidal waters of the St. Croix River - Class B-1."

Little water quality data is available for the Cobscook Bay watershed. The only data found for the basin was collected by the U.S. Geological Survey on the Dennys River at Dennysville, Maine. Their grab sample data which has been collected on a generally once a month basis is summarized in Table 4.

TABLE 4

WATER QUALITY DATA
DENNYS RIVER AT DENNYSVILLE, MAINE
(11/76 - 9/78)

Parameter	Maximum	Minimum	Mean
Water Temp (°C)	24.0	0.0	8.8
Air Temp (°C)	33.0	-12.9	8.7
Conductivity at 25°C (Micromho)	76	24	41

There is a fair amount of agricultural activity in the Cobscook Bay watershed. Several farms are located in the towns of Edmunds, Lubec, Pembroke, and Perry. This indicates the potential for agricultural waste to enter the estuary. Contributions of some amount of fecal coliform, nutrients, and solids are likely.

According to preliminary information developed by the U.S. Fish and Wildlife Service for their forthcoming report "An Ecological Characterization of Maine's Coast North and East of Cape Elizabeth," as of February 1979 there were several industrial discharge permits in effect for the Cobscook Bay area. One fish processing plant in Eastport and five in Lubec had been licensed. Additionally one commercial license was in effect in Lubec. Table 5 presents discharge information for the two industrial operations for which DEP licenses require monitoring.

TABLE 5

INDUSTRIAL EFFLUENTS - COBSCOOK BAY AREA

Receiving Water	Oil & Grease	BOD	Suspended Solids	Fecal Coliform	Discharge	Temperature Range
	(lb/day)	(lb/day)	(lb/day)	($X10^{10}$/day)	(MGD)	(^{o}F)
Eastport Tidewater	802.0	4258.5	2672.0	1.700	0.050	60
Lubec Narrows	1.4	113.6	5.7	--	--	--

c. Cobscook Bay

(1) Tide Ranges - The National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce has maintained a continuous recording tide gage station at Eastport, Maine since September 12, 1929. Tides of an unusually high magnitude are characteristic of Eastport and the entire Cobscook Bay region. They may be classified as semidiurnal with a slight inequality of about one foot between the two highs and two lows during each lunar day (approximtely 24 hours and 50 minutes). The phases of the moon cause monthly tidal variations. The highest or "spring" tides of the month occur near the new or full moon; lowest or "neap" tides occur near the first and last quarters. During the lunar month (approximately 27-1/2 days) two periods of spring tides will occur, one being higher than the other. The higher and lower spring tides occur when the moon is at perigee and apogee, or nearest and furthest from the earth, respectively.

Based on 19 years of records collected between 1941 and 1961 the mean tide range at Eastport was 18.2 feet. The mean spring tide range was 20.7 feet. The highest observed tide ever recorded was 23.4 feet above mean low water (MLW), recorded on 9 January 1978. The lowest observed tide occurred on 7 January 1943, 23 May 1959, and 30 December 1963 with a level 4.4 feet below MLW. The mean sea level elevation and mean tide range at Eastport have been increasing at about 0.01 feet each year reflecting the general sea level rise along the east coast of the United States. The mean tide cycle for Eastport is shown in Figure 22 of the main report.

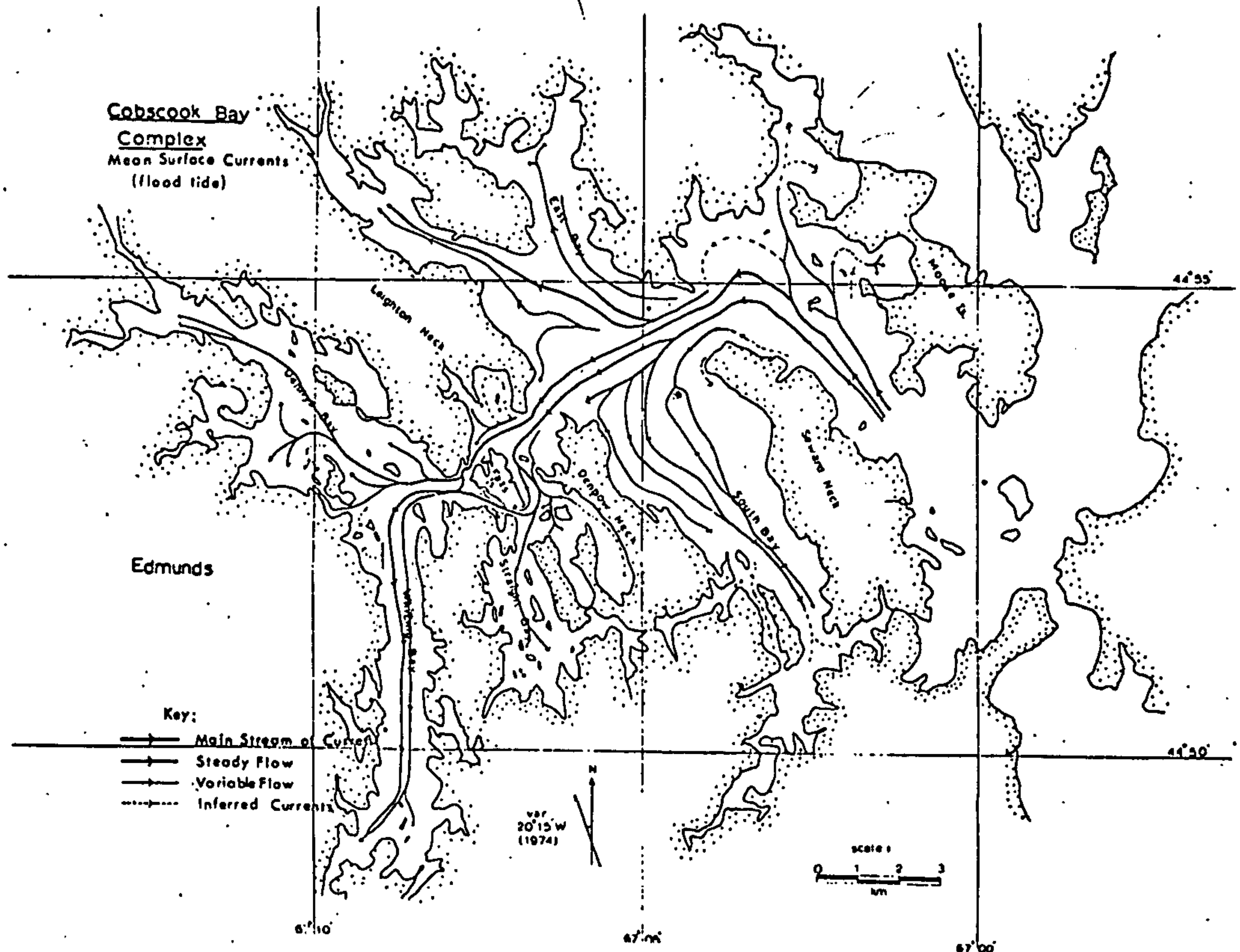
Cobscook Bay can be considered to be divided into two bays at the Falls Island constriction, an outer bay which responds similarly to the Eastport gage, and an inner bay which behaves somewhat differently (see Plate 1). During an early investigation of the potential for tidal power in this area by Dexter P. Cooper, a series of simultaneous tide gage readings were taken during spring tide, December 6, 1927 in and just outside of Cobscook Bay in order to investigate the effect of water surface slopes on power production. These studies revealed that high and low spring tides in the inner bay generally occur within about 1.5 hours after the same tides in the outer bay. The recorded spring tide range for the inner bay was about two feet less than that for the outer bay. Instantaneous elevation differences of as much as 7 feet were observed between inner and outer pools. The bulk of the water surface elevation differential occurs adjacent to Falls Island. Observations were also taken during a neap tide July 16, 1929. These showed about a one hour time lag between inner and outer bays with a neap range difference of about 1 foot. Maximum instantaneous elevation differences of 3 feet were recorded.

(2) Volumetric Exchange - The flow of water between the inner and outer bays was investigated in more detail in 1958 during power studies for the International Passamaquoddy Tidal Power Project. During the spring tide of 8 March 1958 with a range of about 26 feet, an inflow and outflow of 400,000 cfs and 270,000 cfs respectively, were computed to pass Falls Island enroute between outer and inner bays. A maximum head difference of about 8 feet was recorded. During the neap tide of 27 February 1958, with an approximate range of 16 feet and a maximum head difference of about 4 feet, the maximum inflow and outflow were computed at 220,000 cfs and 200,000 cfs, respectively.

The exchange between inner and outer bays has also been determined for the flood and ebb tides of 30 July 1977 (Schroeder, 1977). With a tide range of 22.1 feet during this cycle, a total volume of 86,000 ac/ft passed Falls Island during flood tide, with 109,000 ac/ft passing during ebb tide. The maximum inflowing discharges between Leighton Neck and Falls Island and between Crow Neck and Falls Island were recorded at 200,000 cfs and 120,000 cfs, respectively. Maximum outflowing discharges measured 191,000 cfs and 115,000 cfs, respectively.

(3) Currents - Aerial observations and photography in conjunction with dye streaking have been used to chart surface current patterns in Cobscook Bay during ebb and flood tides (Schroeder, 1977). These are shown on Figures 2 and 4, respectively. Details of the Falls Island area are shown in Figures 3 and 5. Ground truth information for this analysis indicated tidal currents which exceeded 3.3 ft/sec, with some of the more extreme currents in restricted channels exceeding 6.6 ft/sec.

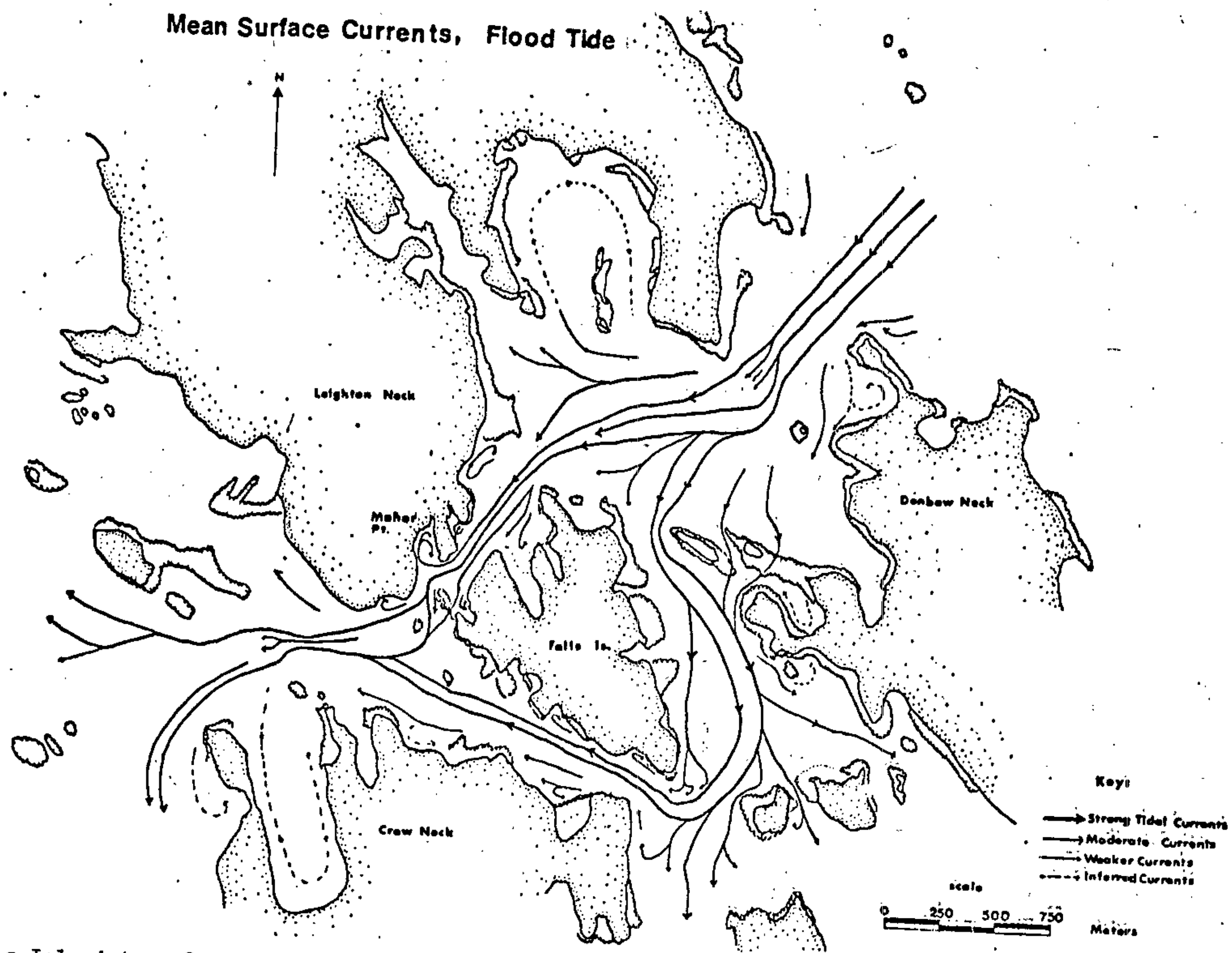
Although little more information is available on tidal currents within Cobscook Bay, considerable information exists for the entrance area to the bay. Studies conducted during 1957-58 for the proposed International Passamaquoddy Tidal Power Project included extensive current measurements. Measurements have also been taken as late as 1973-75 in conjunction with a proposed oil refinery at Eastport.



Cobscook Bay Current Circulation - Flood Tide
August 1977

Figure 2

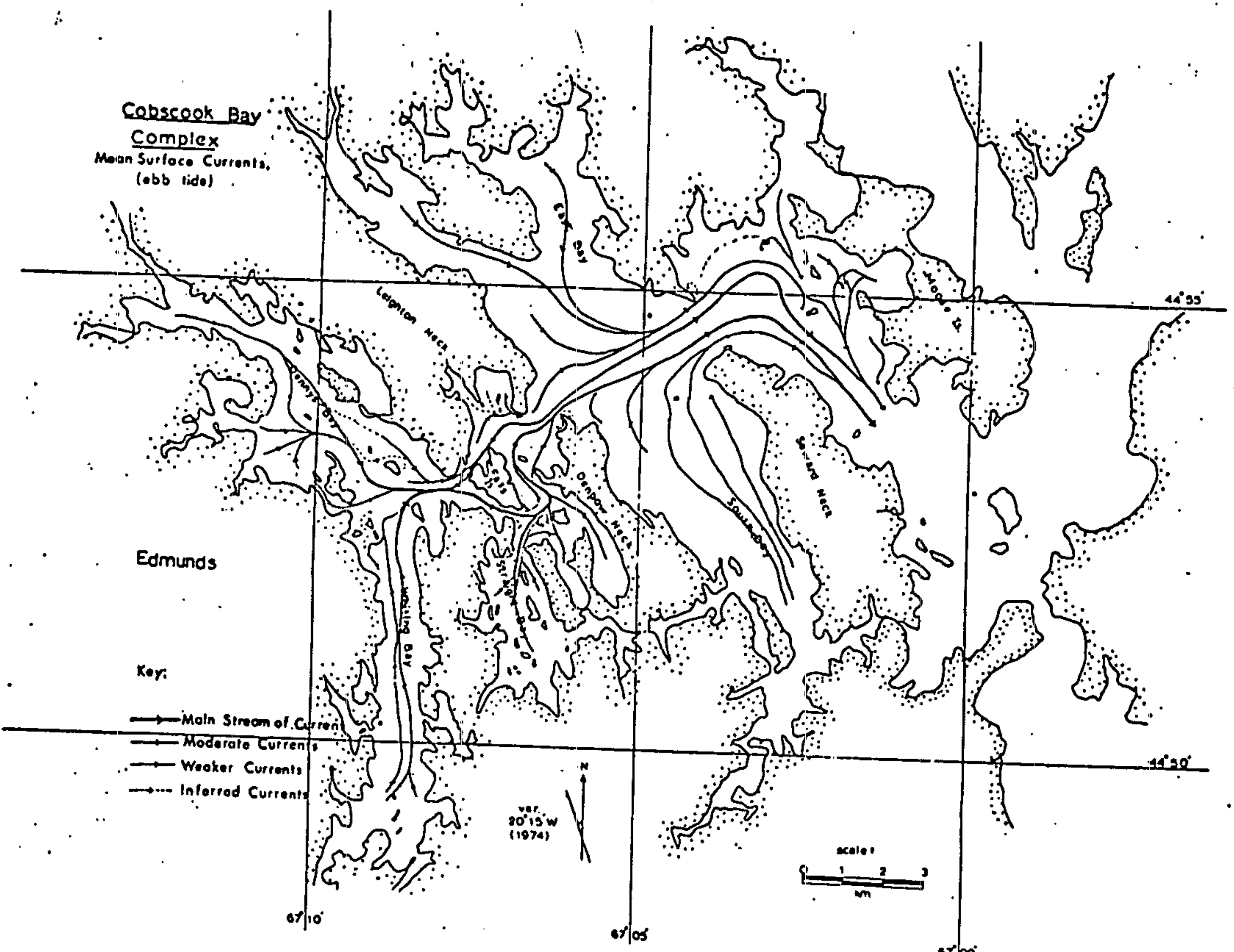
(Schroeder, 1977)



Falls Island Area Current Circulation - Flood Tide
August 1977

Figure 3

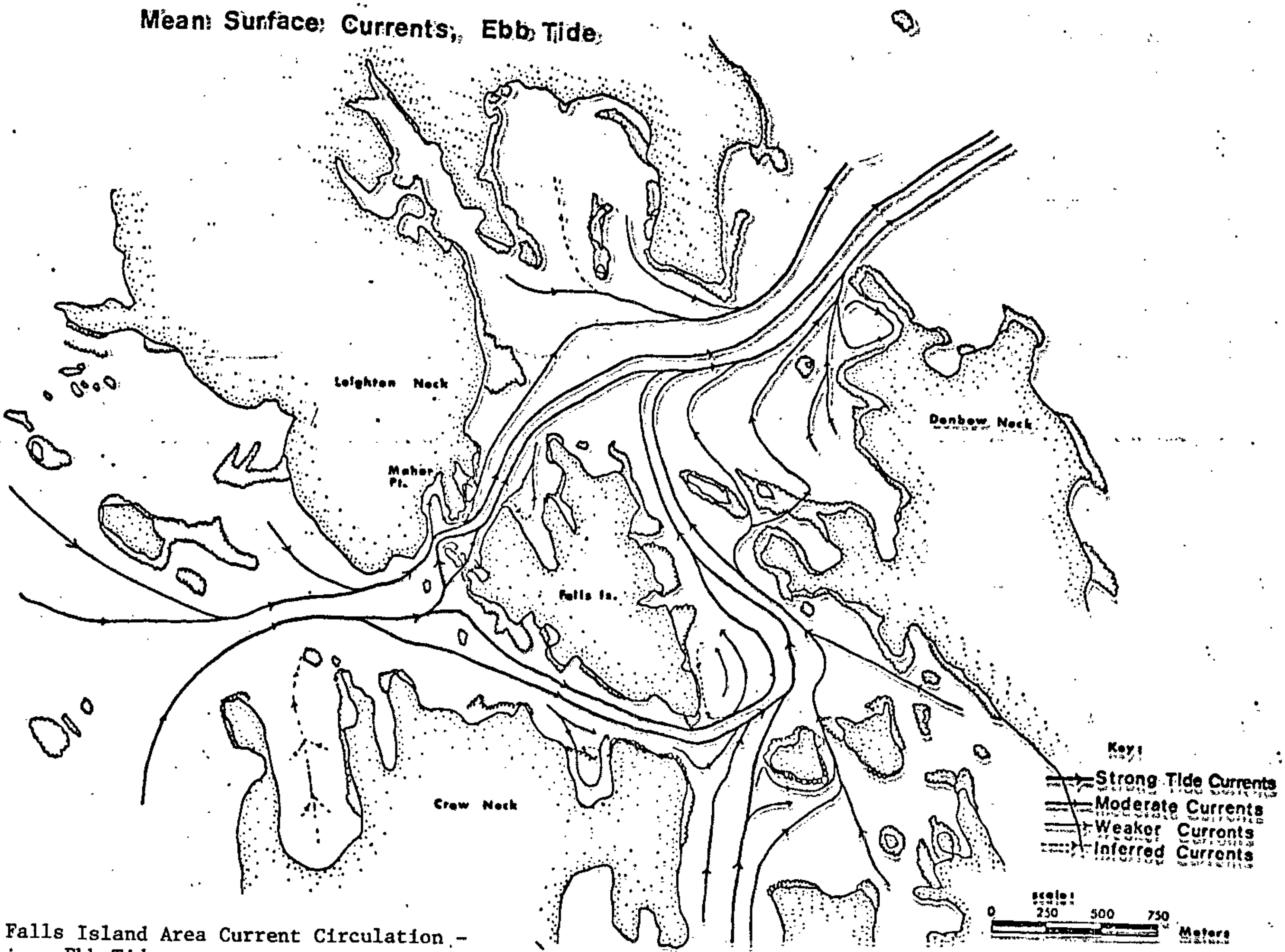
(Schroeder, 1977)



Cobscook Bay Current Circulation - Ebb Tide
August 1977

Figure 4

(Schroeder, 1977)



Falls Island Area Current Circulation - Ebb Tide
August 1977
Figure 5

(Schroeder, 1977)

The best overall picture of the tidal flow pattern for the entire Cobscook Bay - Passamaquoddy Bay system is provided in the work for the International Passamaquoddy Tidal Power Project (see Figures 6 and 7). It shows that the major inflow of water during flood tide to Passamaquoddy Bay is through Western Passage and Letite Passage (Trites & MacGregor, 1962). Tidal currents vary markedly with location. Mean maximum current speed has reached 8 feet per second in Letite Passage. Speeds of less than 1 foot per second are not uncommon in Passamaquoddy Bay. Near the mouth of Cobscook Bay mean maximum speeds of 5 feet per second were recorded. Outside of the bays speeds seldom top 5 feet per second. Maximum current velocity usually occurs in the surface layer and decreases slowly with depth (Forrester, 1960).

The Research Institute of the Gulf of Maine, (TRIGOM, 1973), reports from their studies that between Eastport and Seward Neck at Shackford Head (Plate 1) the greatest mean hourly velocity recorded was 4.9 feet per second during flood tide and the maximum mean hourly velocity during ebb tide was 4.3 feet per second. Mean velocities of about 3.0 feet per second or greater exist for four hours before and after high tide.

Moored meter channel current measurements by EG&G, Inc. and Atlantic Oceanographic Laboratories reveal that currents in Head Harbor Passage and off Broad Cove near Eastport (Plate 1) are generally consistent in speed and direction. Currents are nearly parallel to channel centerline during ebb and flood tides. Maximum current speed varies at each location with time in the lunar cycle. At the entrance to Head Harbor, maximum and minimum daily peak current speeds of 4.2 and 1.7 feet per second (fps) were recorded during spring and neap tides, respectively. Respective measurements at other locations included: near Casco Island (Figure 7) 6.8 and 3.0 feet per second; opposite Western Passage, 5.1 and 2.0 feet per second; and, opposite Broad Cove, near Eastport, 8.4 and 3.0 feet per second.

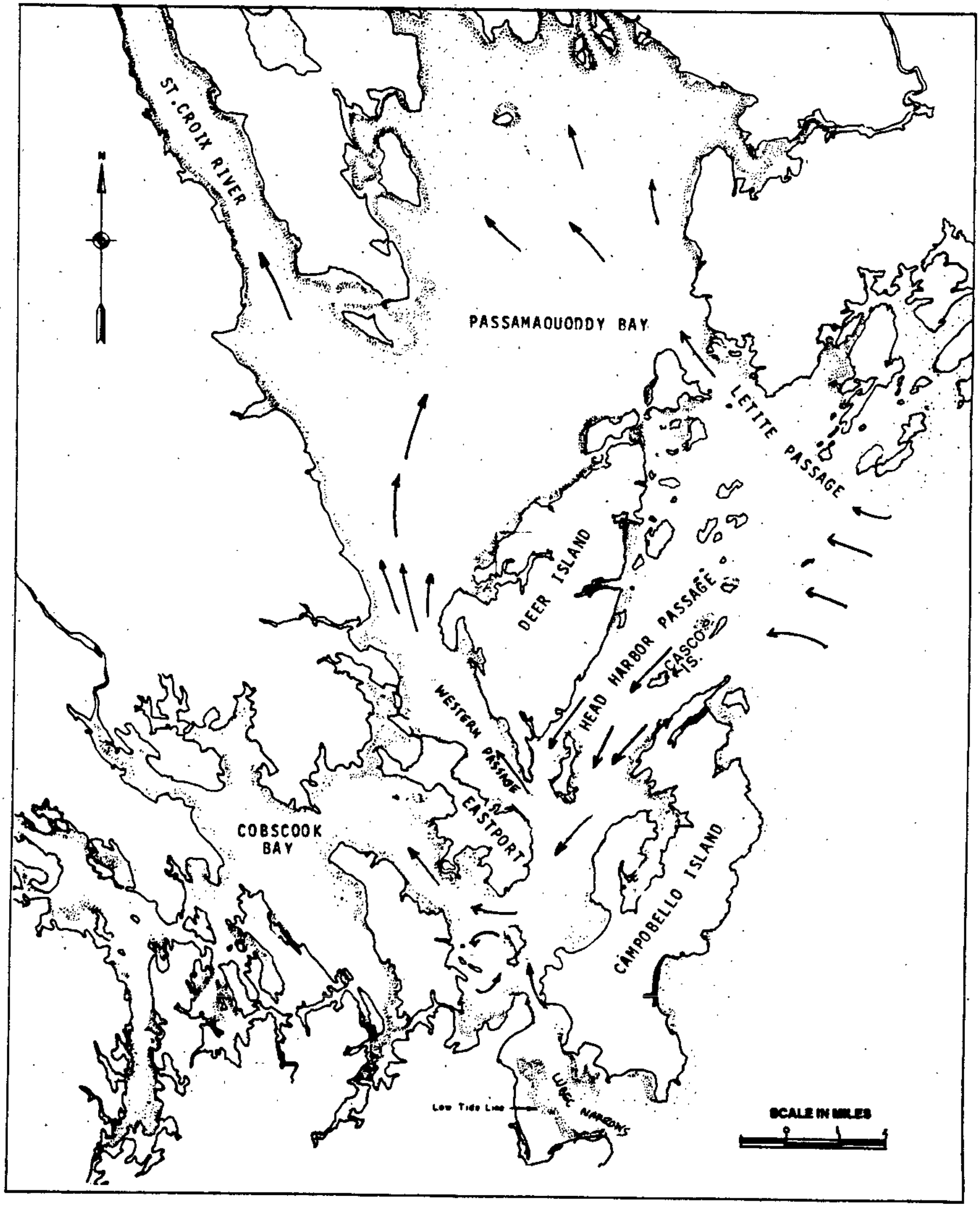
The primary factor causing high velocity currents in the Passamaquoddy-Cobscook Bay area is the large tidal range. Residual currents due to surface runoff are small and wind induced currents are relatively insignificant. Measured tidal currents indicate a consistently repetitive pattern varying directly with tidal range. Predicted and observed tidal ranges correspond very closely indicating that currents in this area are generally predictable.

The distance a particle of water or a floating object will travel between high water slack and low water slack, or reverse, is referred to as tidal excursion. Based upon intertidal volumes and flood current knowledge of the Head Harbor Passage, this ranges from five to eight miles in the inner Quoddy region (Forgeron, 1959; Louches, et al, 1973).

Currents which are not caused by tidal flow are referred to as residual currents. These currents indicate the net flow of water in the tidal area. They result from river runoff, wind, unequal heating and cooling of surface water and the effect of the Coriolis force (earth's rotation) on

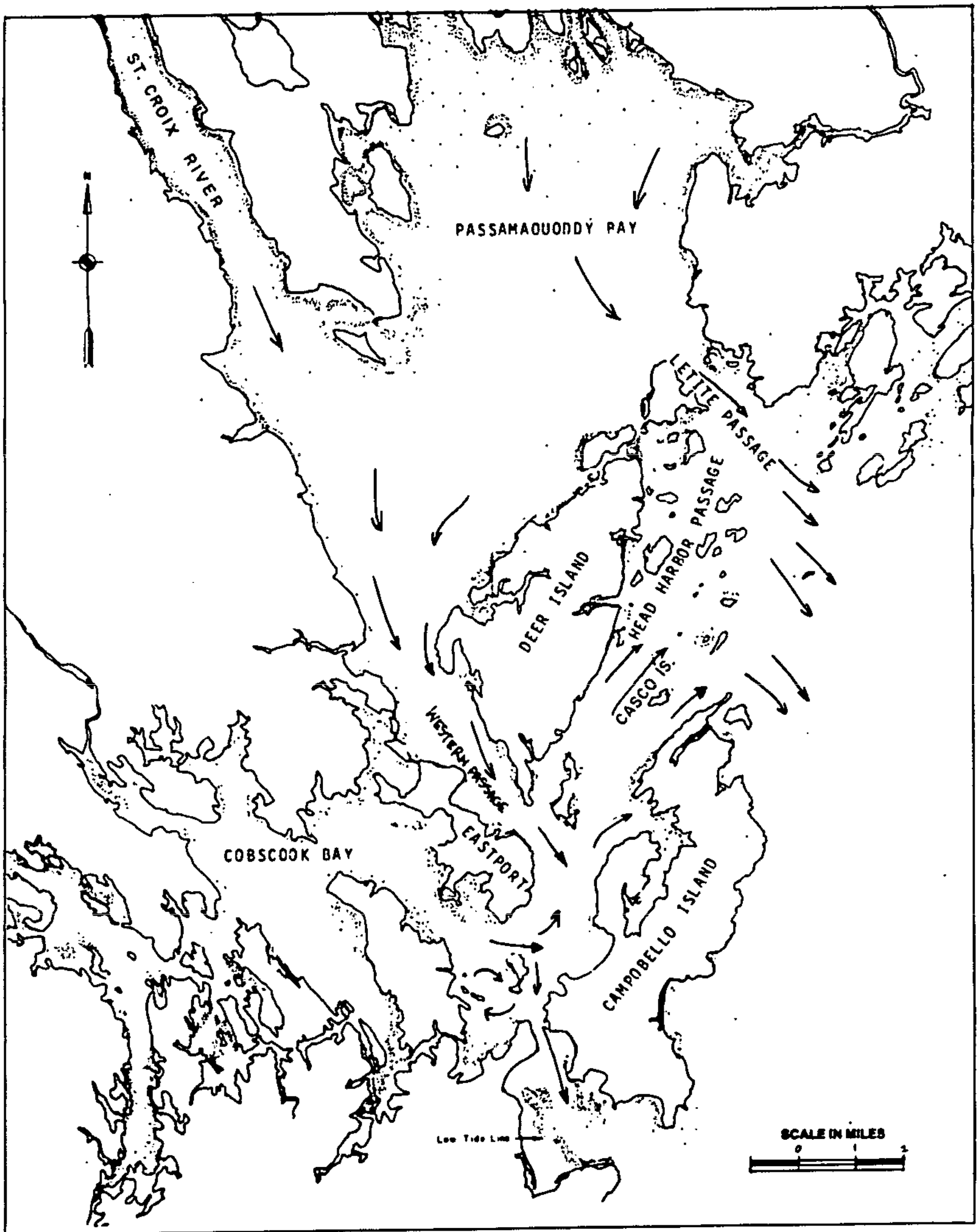
FLOOD TIDAL CURRENT PATTERNS IN QUODDY REGION

FIGURE 6



EBB TIDAL CURRENT PATTERNS IN QUODDY REGION

FIGURE 7



the tidal motion of confined waterways. In this region drift bottle experiments have been conducted to determine the magnitude and circulation pattern of these currents (Bumpus, 1959; Chevrier, 1959; Graham, 1970). Residual speeds in the Quoddy region have been measured at less than 0.9 fps (Forrester, 1959).

Residual surface flow in Cobscook Bay is towards Friar Roads (Plate 1). Outflow then proceeds through both Lubec Narrows (Plate 1) and the eastern side of Head Harbor Passage. Inflow comes along the western side of the Passage and the eastern shore of Deer Island (Figure 7), extending to Western Passage. Outflow from Western Passage carries this water toward Campobello and adds to the net outflow along the islands western shore.

Net surface circulation in Passamaquoddy Bay is characterized by outflow through Western Passage, flow from St. Croix estuary into Passamaquoddy Bay, counterclockwise circulation within the bay, and both inflow and outflow through Letite Passage. Southerly winds confine the waters in the bay and northerly and westerly winds promote a net outflow of surface waters.

The season, the winds, and freshwater runoff affect the outflow at Head Harbor Passage. It may move northeasterly before turning south, directly southwest, or southward. The residual drift magnitude is significantly affected by wind speed and direction.

Upon exiting Head Harbor passage, the waters of the Quoddy region enter either the large, counterclockwise gyre which dominates surface circulation in the Gulf of Maine, or the smaller counterclockwise gyre of the Bay of Fundy (see Figure 8). In the first case, waters head south toward Cape Cod, and in the latter, they traverse the mouth of the Bay of Fundy headed toward Nova Scotia. In the Bay of Fundy, net inflow circulation is along the Nova Scotia coast and outflow is along the bays western side. These counterclockwise gyres are likely due to the combined effects of the Coriolis force and freshwater discharges along the coastline.

(4) Water Quality - Standards for the classification of marine waters in the State of Maine have been developed by the Department of Environmental Protection. Applicable standards from "Classification of Surface Waters," Department of Environmntal Protection, State of Maine, October 1977 are summarized in Table 6.

DOMINANT NON—TIDAL CIRCULATION OF THE GULF OF MAINE (JULY-AUGUST)

FIGURE 8

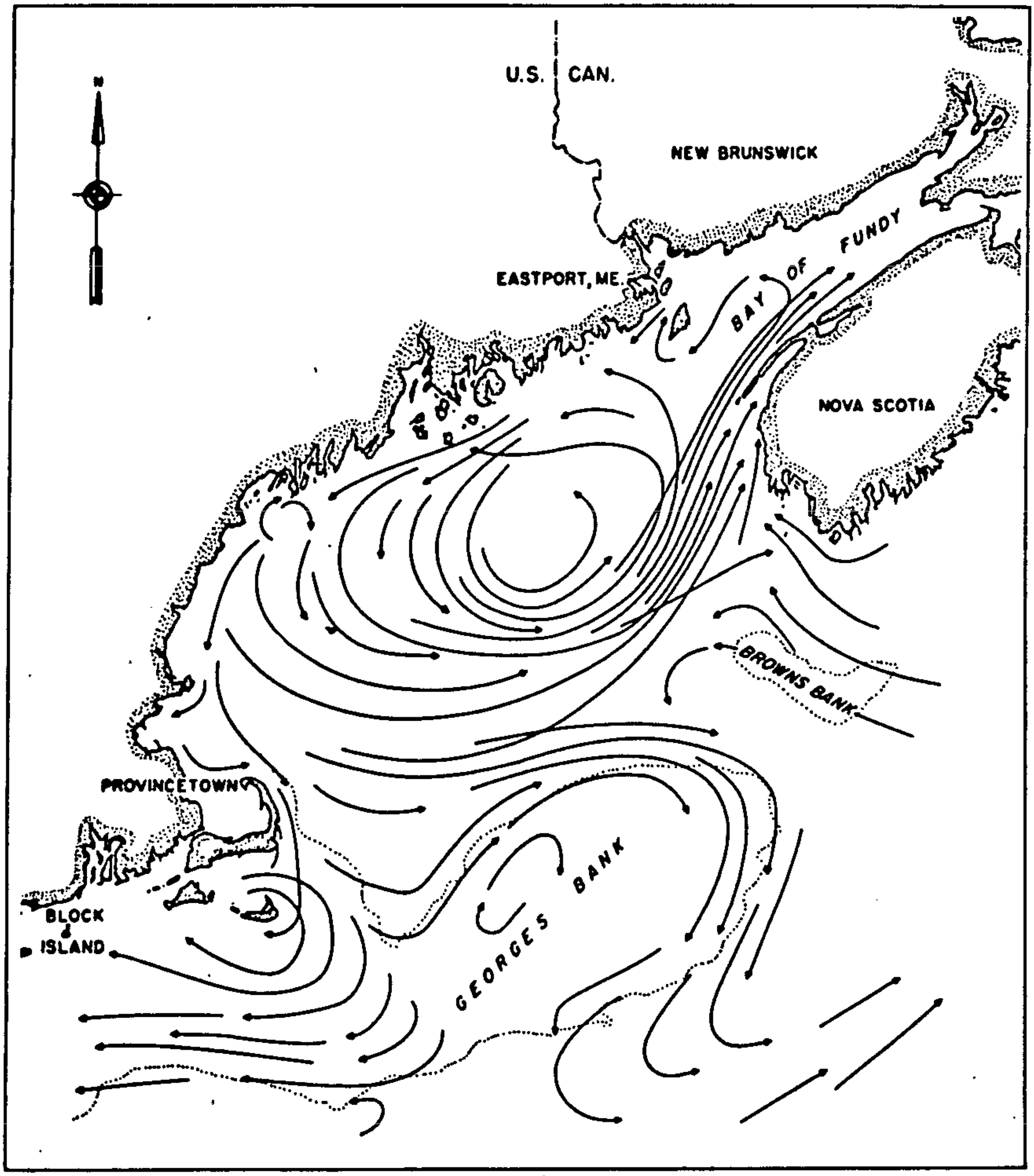


TABLE 6

STATE OF MAINE WATER QUALITY STANDARDS FOR CLASSIFICATION OF TIDAL OR MARINE WATERS

Class	Uses	Prohibitions	Criteria
SA	1. Clean water usages 2. Water contact recreation 3. Fishing 4. Harvesting and propagation of shellfish. 5. Fish and wildlife habitat	1. Floating solids, settleable solids, oil, or sludge deposits from sewage, industrial or other wastes. 2. Deposit of garbage, cinders, ashes, oils, sludge or other refuse. 3. Discharge of sewage or other wastes not receiving adequate treatment or lowering the standards or altering class usages, or injuring aquatic life or making them unfit for human consumption. 4. Discharge of toxic wastes. deleterious substances, colored or other wastes or heated liquids injurious or detrimental to edible fish or shellfish or to make bathing unsuitable or impair other class uses. 5. Discharge causing pH to fall outside 6.7 to 8.5 range. 6. Disposal of chemical constituents being harmful to humans, animal or aquatic life, or adversely affecting class uses. 7. Radioactive matter harmful to humans, animal or aquatic life or causing aquatic life to be inedible for human consumption. 8. Any matter altering bottom fauna composition, or physical and chemical nature of bottom material, or interfering with fish or shellfish propagation.	1. D.O. - not less than 6.0 ppm 2. Coliform - median number not to exceed 70 per 100 milliliters, not more than 10% of samples exceeding 230 per 100 milliliters. 3. Fecal coliform - median number not to exceed 14 per 100 milliliters, not more than 10% of samples exceeding 43 per 100 milliliters.
SB-1	Same as Class SA	Same as Class SA	1. D.O. - not less than 6.0 ppm 2. Coliform - (shellfish growing area) median number not to exceed 70 per 100 milliliters, not more than 10% of samples exceeding 230 per 100 milliliters. 3. Fecal coliform (shellfish growing area) - median number not to exceed 14 per 100 milliliters, not more than 10% of samples exceeding 43 per 100 milliliters.

TABLE 6 (Cont.)

Class	Uses	Prohibitions	Criteria
			4. Coliform (nonshellfish growing area) - median number not to exceed 240 per 100 milliliters, not more than 10% of samples exceeding 50 per 100 milliliters. 5. Fecal coliform (nonshellfish growing area) - median number not to exceed 50 per 100 milliliters, not more than 10% of samples exceeding 150 per 100 milliliters.
SB-2	1. Recreational usages 2. Water contact 3. Fishing 4. Harvesting and propagation of shellfish 5. Fish and wildlife habitat 6. Industrial cooling and process use	Same as Class SA	1. D.O. - no less than 6.0 ppm. 2. Coliform (shellfish growing area) - median number not to exceed 70 per 100 milliliters, not more than 10% of samples exceeding 230 per 100 milliliters. 3. Fecal coliform (shellfish growing area) - median number not to exceed 14 per 100 milliliters, not more than 10% of samples exceeding 43 per 100 milliliters. 4. Coliform (nonshellfish growing area) - median number not to exceed 500 per 100 milliliters, not more than 10% of samples exceeding 1000 per 100 milliliters. 5. Fecal coliform (nonshellfish growing area) - median number not to exceed 100 per 100 milliliters, not more than 10% of samples exceeding 200 per 100 milliliters.

TABLE 6 (Cont.)

Class	Uses	Prohibitions	Criteria
SC	1. Recreational boating 2. Fishing 3. Other similar uses except water contact. 4. Propagation of indigenous shellfish to be harvested for depuration purposes. 5. Fish and Wildlife habitat 6. Industrial cooling and process uses.	1. Floating solids, settleable solids, oil, or sludge deposits from sewage, industrial waste, or other wastes. 2. Deposit of garbage, cinders, ashes, oils, sludge, or other refuse. 3. Discharge of sewage or other wastes not receiving adequate treatment or lowering the standards or altering class usages, or injuring aquatic life or making them unfit for human consumption. 4. Discharge of toxic wastes, deleterious substances, colored or other wastes or heated liquids to be injurious or detrimental to edible fish or shellfish or impair other class uses. 5. Discharge causing pH to fall outside 6.7 to 8.5 range. 6. Disposal of chemical constituents being harmful to humans, animal or aquatic life, or adversely affecting class uses. 7. Radioactive matter harmful to humans, animal or aquatic life or causing aquatic life to be inedible for human consumption.	1. D.O. - not less than 5 ppm. 2. Coliform (shellfish growing area) - median number not to exceed 700 per 100 milliliters, not more than 10% of samples exceeding 2300 per 100 milliliters. 3. Fecal coliform (shellfish growing area) - median number not to exceed 150 per 100 milliliters, not more than 10% of samples exceeding 500 per 100 milliliters. 4. Coliform (nonshellfish growing area) - median number not to exceed 1500 per 100 milliliters, not more than 10% of samples exceeding 5000 per 100 milliliters. 5. Fecal coliform (nonshellfish growing area) - median number not to exceed 300 per 100 milliliters, not not more than 10% of samples exceeding 1000 per 100 milliliters.

Based upon the above classification system the marine waters of the Cobscook Bay area have been classified by the State of Maine, DEP. This classification is shown on plate 2. Except for the waters adjacent to Eastport and Lubec, and the tips of several of the sub-bays, the bulk of Cobscook Bay received the highest possible classification, "SA," indicating good overall water quality within the bay.

No regular program of water quality analysis is known to exist for Cobscook Bay. However, several short term efforts have taken place within the past several years.

In September and October 1975, Enviro-Sciences, a consultant to the Pittston Oil Company, contracted with Bigelow Laboratory to conduct sampling and analysis of the tidewaters of Broad Cove, Deep Cove, Cobscook Bay and Head Harbor Passage as a part of environmental studies for the proposed refinery at Eastport. The sample results, shown in Table 7, met both applicable usage and quantitative standards. October dissolved oxygen levels ranged from a low of 6.6 mg/l in Broad Cove to 9.4 mg/l in Cobscook Bay, which is greater than 100 percent saturated. Nutrient levels at all four locations were high, although standards were met. All samples were low in oil and grease and colform bacteria.

TABLE 7

ANALYSES OF TIDAL WATER IN EASTPORT AREA

Location	Broad Cove			Deep Cove			Cobscook Bay			Head Harbor		
Sample Date 1975	9/16	10/16	11/20	9/16	10/16	11/20	9/16	10/16	11/20	9/16	10/16	11/20
Temperature, ^{o}C	12.5	10.0	8.0	11.0	10.0	8.0	11.0	8.5	8.0	11.0	9.9	9.0
Salinity	31.98	32.26	31.66	31.95	32.23	31.48	31.89	32.28	31.71	31.92	32.27	31.8
pH	7.3	7.72	--	7.44	7.77	--	7.58	7.73	--	7.29	7.76	--
Secchi Disk, m	4.0	7.0	--	8.0	7.0	--	9.0	7.0	--	7.5	8.5	--
Oxygen, ppm	7.7	6.6	--	8.1	8.7	--	7.8	9.4	--	8.3	8.7	--
Chl, mg/m^3	0.53	0.12	--	0.39	0.18	--	0.40	0.18	--	0.46	0.18	--
Oil & Grease, mg/l	0.16	0.23	--	0.15	0.01	--	0.18	0.11	--	0.16	0.11	--
BOD, mg/l	--	1.96	--	--	--	1.81	--	--	2.72	--	--	2.42
Coliforms/100 ml												
Total	240	3	23	3	3	9.1	--	3	3.6	3	3	43
Fecal	--	--	3.6	--	--	3	--	--	3	--	--	3
Nutrients microgram-atoms/l												
NO_2	0.33	0.36	--	0.28	0.34	--	0.32	0.34	--	0.32	0.36	--
NO_3	5.39	8.44	--	6.88	8.18	--	6.17	7.11	--	7.79	7.92	--
NH_4	5.02	1.49	--	4.16	1.08	--	1.23	1.08	--	1.26	2.60	--
PO_4	0.53	1.01	--	0.77	0.83	--	0.67	0.94	--	0.61	0.90	--

Source: Bigelow Laboratory Report, Pittston EIS

Suspended sediment analyses have been performed for 10 sites throughout the outer bay and 5 sites in the inner bay (Schroeder, 1977). Surface and bottom suspended sediment samples were gathered at flood and ebb tides. Comparisons between tide cycles in relation to the total suspended sediments in the water column are shown in Table 8. Suspended sediments with respect to inner and outer bays are shown in Table 9. All mean surface and bottom values recorded for each tidal cycle and location are shown. The percentage of organics by weight of the total load is also listed. These results tend to indicate that the quantity of suspended matter in the water column is generally homogeneous in nature, with fairly high levels of organics present. The mean suspended sediment concentration for the inner bay at ebb tide appeared higher than the other values. It has been suggested that this is due to local resuspension of particulate matter in the water column during seaward flow and deposition as the new water flows inward.

TABLE 8

SUSPENDED SOLIDS DATA - JULY 1977
(mg/l)

	EBB TIDE		FLOODTIDE	
	Surface	Bottom	Surface	Bottom
Mean, Total Load	3	4	3	3
Range, Total Load	8	9	5	5
Standard Deviation	2	2	1	1
% Organic by Weight	60%	50%	70%	50%
Standard Deviation	0.6	0.8	1.2	0.9

(Schroeder, 1977)

TABLE 9

SUSPENDED SOLIDS DATA - JULY 1977
(mg/l)

	EBB TIDE		FLOODTIDE	
	Outer Bay	Inner Bay	Outer Bay	Inner Bay
Mean, Total Load	3	6	3	3
Range, Total Load	5	8	5	4
Standard Deviation	1	3	1	1
% Organic by Weight	40%	60%	60%	70%
Standard Deviation	0.6	1.2	0.6	1.5

(Schroeder, 1977)

The volume of the bays and estuaries of the Quoddy region is large compared to the volume of freshwater which enters them. This accounts for the relatively high salinity of these waters as shown in Table 10. However, the salinity decreases at the mouth of rivers, such as the St. Croix.

The lowest salinity values are coincident with the greatest river discharges to the bays which occur in the spring of the year. Higher salinity is characteristic of late summer when river runoff is lowest.

Generally speaking, the seasonal distribution of water temperature is related to depth and air temperature. Therefore, during summer months, the surface waters tend to be warmer than deeper waters. The heat exchange between water and air causes the reverse to be true during the winter. The strong influence of tides resulting from the great tidal ranges of this region cause both vertical and horizontal mixing of the waters. This minimizes extremes of both temperature and salinity as shown in Table 11. More recent work in Cobscook Bay itself reinforces these observations.

TABLE 10

AVERAGE SEASONAL AND ANNUAL TEMPERATURES AND SALINITIES IN THE QUODDY REGION

	1957		1958	
	Temp. °C	Salinity ppt	Temp. °C	Salinity ppt
Cobscook Bay				
Winter	1.57	31.51	3.14	31.56
Spring	6.08	31.70	6.74	30.85
Summer	11.23	31.88	11.12	32.30
Autumn	8.99	32.37	8.98	32.20
Mean	6.67	31.87	7.50	31.73
Passamaquoddy Bay				
Winter	1.02	31.35	2.89	31.06
Spring	6.39	31.24	6.07	29.40
Summer	11.79	31.85	11.70	31.44
Autumn	9.50	32.35	8.67	31.85
Mean	7.18	31.92	7.33	30.94
Letite Passage				
Winter	1.50	31.80	3.51	31.91
Spring	5.95	31.72	5.59	30.91
Summer	11.10	32.21	10.62	31.85
Autumn	9.43	32.61	8.79	32.14
Mean	6.99	32.09	7.13	31.70
Western Passage				
Winter	1.72	31.75	3.19	31.64
Spring	5.71	31.83	5.50	31.00
Summer	10.86	32.29	10.47	31.85
Autumn	9.46	31.73	9.11	32.18
Mean	6.94	32.15	7.07	31.67
Outside Waters				
Winter	2.60	32.35	3.79	32.20
Spring	4.99	32.05	4.92	31.39
Summer	10.21	32.35	9.68	32.12
Autumn	9.62	32.70	9.21	32.47
Mean	6.86	32.36	6.90	32.06

TABLE 11

DIFFERENCES BETWEEN TEMPERATURE AND SALINITY AT HIGH WATER AND AT LOW WATER
(Values at High Water Minus Values at Low Water)

	St. Croix Estuary			
	June 1958		August 1958	
Station No.	Temperature	Salinity	Temperature	Salinity
3	-0.22	2.01	-0.45	0.18
4	-0.38	1.16	-0.26	1.82
5	--	--	-0.36	1.03
6	-0.27	0.43	-0.65	0.76
Mean	-0.29	1.20	-0.41	0.95
	Magaguadavic Estuary			
4	-0.43	2.98	0.17	1.51
5	0.38	0.63	-0.30	0.44
Mean	-0.03	1.81	-0.07	0.98
	Passamaquoddy Bay			
	April 1952		October 1952	
Eastern	0.06	0.99	0.50	-0.01
Western	-0.39	1.10	0.17	-0.06
Mean	-0.17	1.05	0.34	-0.04

Passages and Outer Quoddy	April 1952	
	Temperature	Salinity
Letite	-0.30	1.25
Western and Head Harbour	-0.30	0.05
Outer Quoddy	-0.08	0.41

Temperature, salinity, and dissolved oxygen profiles have been taken at various locations in the inner and outer bays of the Cobscook Bay system (Surgens, 1978). Representative profiles for the centerline of the outer bay and for Dennys Bay at flood and ebb tide are shown in figures 9 through 12.

Tidal mixing has produced nearly homogenous temperature, salinity, and dissolved oxygen conditions within the water column on the centerline at the outer bay. This appears to be true of all locations in the bay, except for the most peripheral stations. During floodtide the greatest degree of vertical homogeneity was present. Some temporary stratification was noted in the tips of the bays during the ebb tide. This effect was diminished once tidal mixing resumed. Dennys Bay is probably one of the better examples of this phenomenon since it is the location of the major freshwater inflow to the bay.

d. Conclusions - The large tidal fluctuation in the Cobscook Bay area causes a great amount of water to enter and leave the bay during the tide cycle. A very dynamic situation exists with high velocities and everchanging currents present, and, as a result, the Cobscook Bay waters are completely mixed. The waters of the bay are classified at the highest quality with the exception of some small areas near the greater population concentrations.

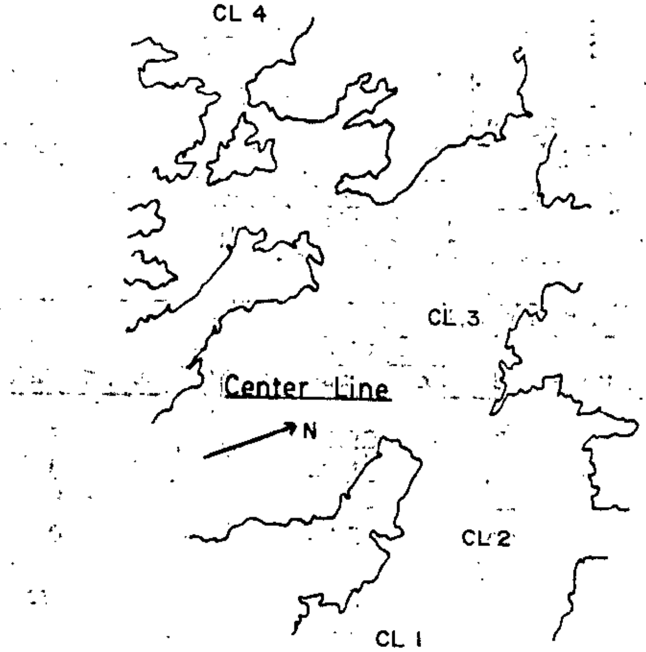
The freshwater inflows to Cobscook Bay are also classified as good in water quality. The freshwater inflows are small compared to the tidal exchange of water in the bay, therefore they have little effect on the bay as a whole. Their effect appears limited to the immediate area of their entrance to the bay where some temporary stratification occurs.

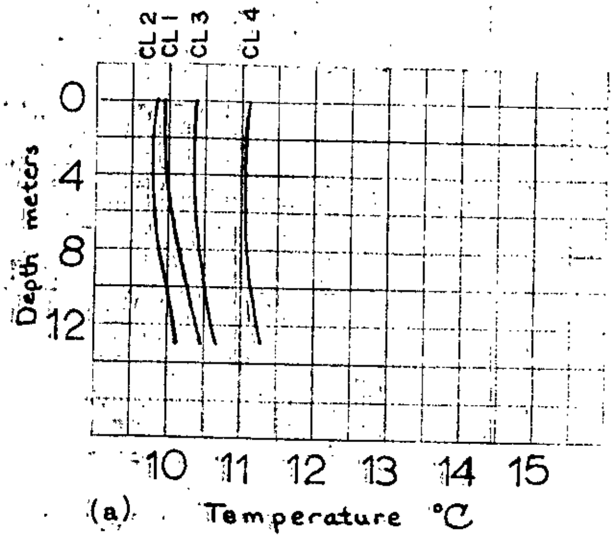
3. FUTURE WATER QUALITY CONDITIONS

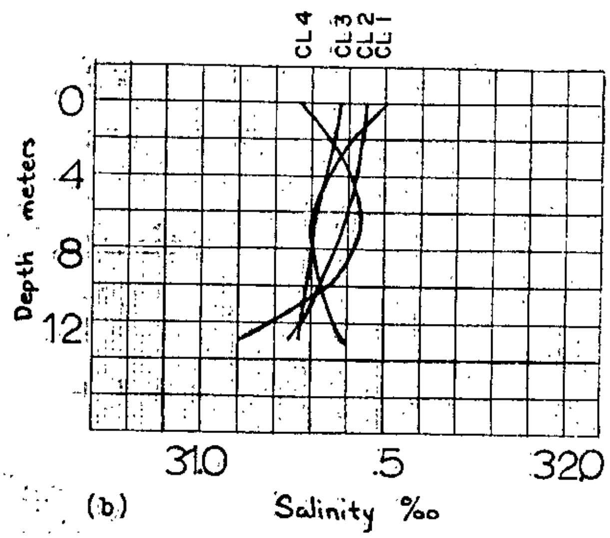
a. General - In this section possible future water quality conditions which could exist in and around Cobscook Bay during and after construction of the proposed tidal power project will be examined. Since this discussion is based solely on literature review no specific predictions regarding proposed alignments can be made. Only with more detailed analysis (Section 4) can these types of predictions be attempted.

Initially the proposed project alternatives will be briefly mentioned. The likely cycle of operation and effect on water levels and flow conditions will be examined, and the potential effect on the tidal conditions of the general area will be discussed. Potential effects on temperature, salinity, dissolved oxygen levels and sedimentation will also be treated.

b. Project Layout - Several alternate embankment locations have been proposed for the Cobscook Bay Tidal Power Project (Plate 1). Four single pool plans, (Dudley, Goose, Birch, and Wilson) have been advanced. All of these plans, except Wilson, would employ the inner bay as part of the high pool. Wilson would utilize only East Bay and the Pennamaquan River Estuary as the high pool. Behind any of these embankments, current hydraulic conditions would be significantly altered.







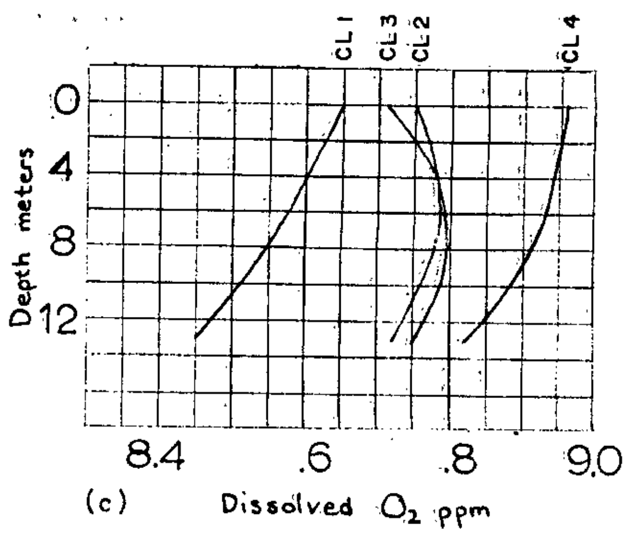


Figure 9
Center Line: Flood Tide
Mean values of
(a) Temperature
(b) Salinity
(c) Dissolved Oxygen

for average surface, mid, and bottom depths over the period July 3, 1978 to August 5, 1978

(Surgens, 1978)

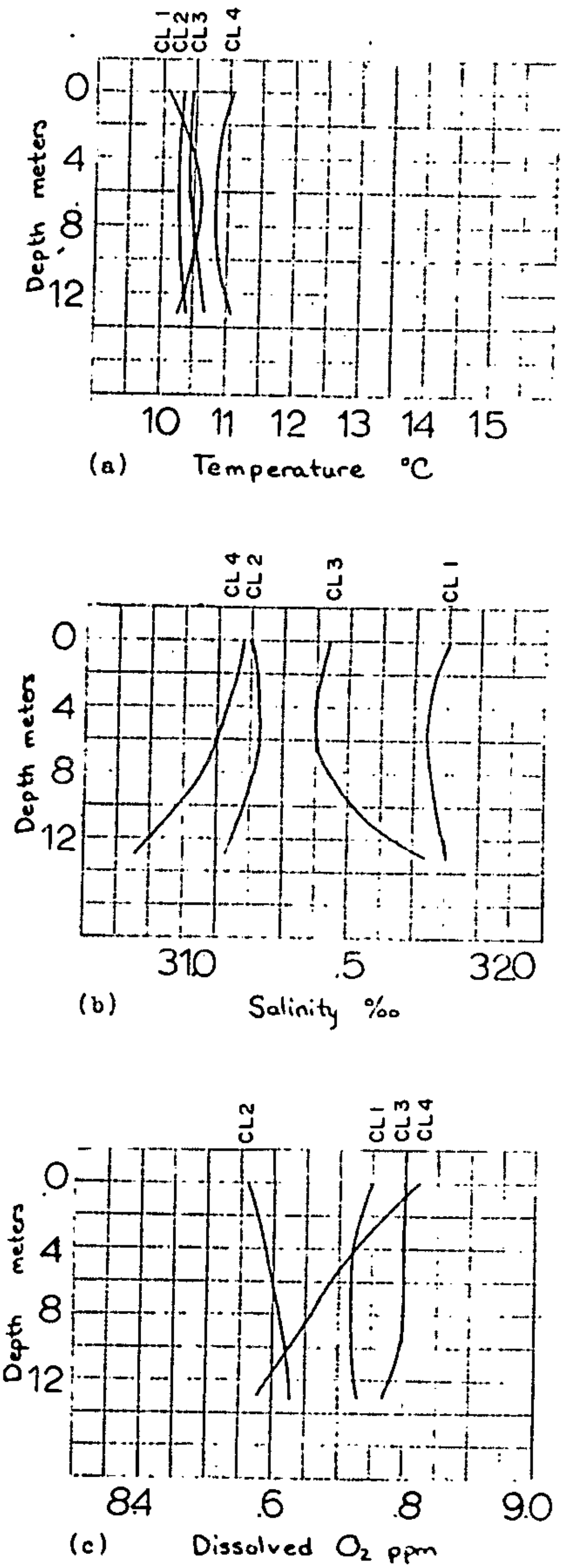
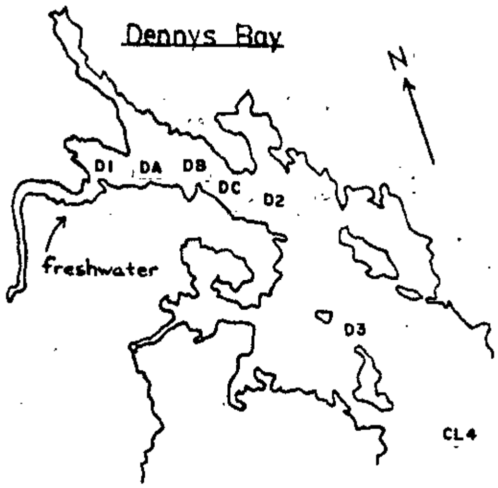


Figure 10
Center Line: Ebb Tide
Mean values of
(a) Temperature
(b) Salinity
(c) Dissolved Oxygen

for average surface, mid, and bottom depths over the period July 3, 1978 to August 5, 1978

(Surgens, 1978)



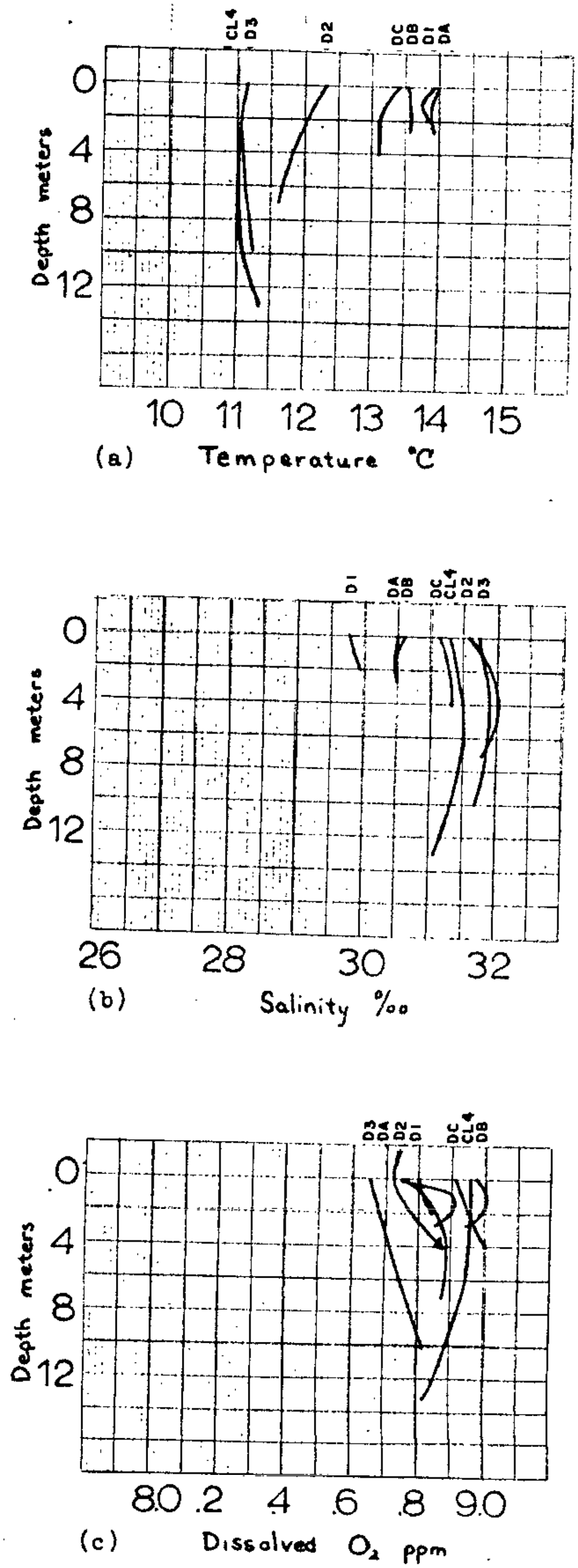


Figure 11
Dennys Bay: Flood Tide
Mean values of
(a) Temperature
(b) Salinity
(c) Dissolved Oxygen

for average surface, mid, and bottom depths over the period July 3, 1978 to August 5, 1978

(Surgens, 1978)

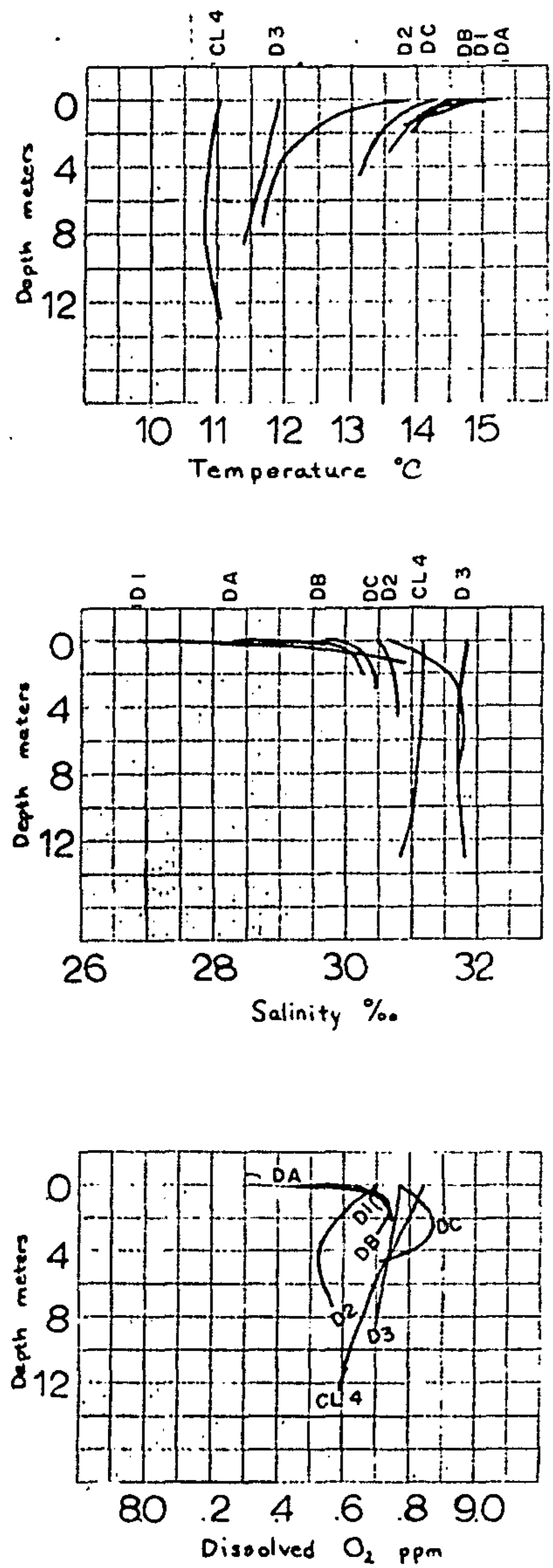


Figure 12
Dennys Bay: Ebb Tide
Mean values of
(a) Temperature
(b) Salinity
(c) Dissolved Oxygen

for average surface, mid, and bottom depths over the period July 3, 1978 to August 5, 1978

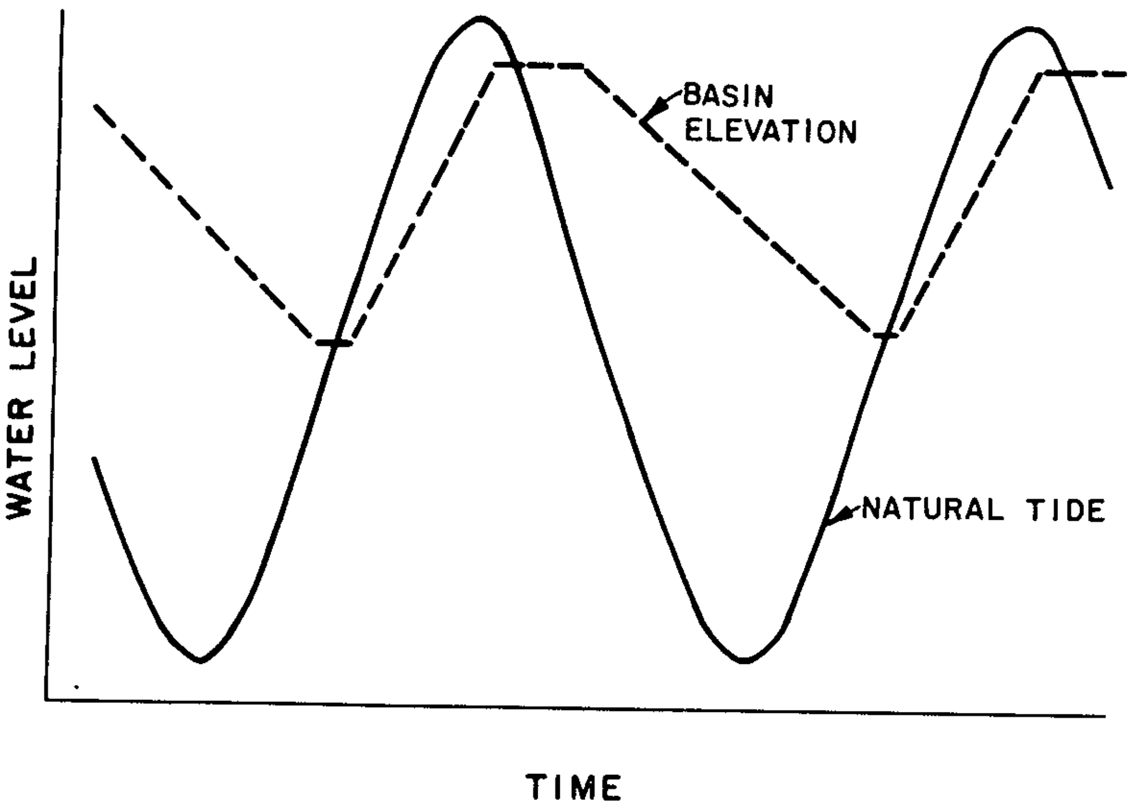
(Surgens, 1978)

c. <u>Cycle of Operation</u> - Generally speaking, a single pool tidal power project operates by opening filling gates during the rising tide. In this manner the operating pool is filled to near the high tide level. The filling gates are then closed, and the turbines begin generation during the falling tide when a differential head exists at the embankment. The cycle is then repeated. Project operation is explained in greater detail in the main report. Figure 13 shows a typical operation cycle for a single pool plan. Exact basin elevations for this project would depend on the results of refined hydropower studies.

d. <u>Water levels and Flow Conditions</u> - The mean tide range in the operating pool of each alternative plan will be between 4.7 feet and 10 feet depending upon selection of a 0.5 or 0.2 plant factor. Figure 22 of the main report, shows possible operating pool levels for various installed capacities compared with the natural mean tide levels. Regardless of which operating curve is adopted, water surface levels and rates of filling and drawdown will be significantly changed, however, the mean maximum tidal level will be within about one foot of the current level.

Filling of the operating pool will be through a series of 30 foot by 30 foot filling gates. Maximum velocities through these gates are estimated to be near 20 feet per second. Bulb type turbines will be provided to generate electricity, and exit velocities will be in the range of 18 feet per second. Table 12 provides information on inflows and outflows for the maximum and minimum plant factors evaluated.

Currents within and immediately outside of the power pool will be significantly affected in magnitude and direction. The volume of water passing the embankment site will be considerably less than at present and will be concentrated through the turbine and filling gate openings. Reduced currents in the operating pool will have a tendency to decrease the degree of mixing which currently takes place. Residual currents outside the pool would be minimally affected.



TYPICAL BASIN LEVELS FOR A SINGLE BASIN
BASIN TO SEA SCHEME

FIGURE 13

TABLE 12

PERTINENT DATA
ALTERNATE EMBANKMENT SITES
COBSCOOK BAY TIDAL POWER PROJECT

Embankment Alignment	Surface Area (High+Mean)/2	Maximum Filling Rate 0.20 Plant Factor	Maximum Filling Rate 0.50 Plant Factor	Maximum Generating Rate 0.20 Plant Factor	Maximum Generating Rate 0.50 Plant Factor
	(acres)	(10^5 cfs)	(10^5 cfs)	(10^5 cfs)	(10^5 cfs)
Dudley	23,123	9.2	5.1	14.	1.7
Goose	19,379	7.7	4.3	12.	1.4
Birch	16,582	6.4	3.7	10.	1.2
Wilson	3,552	1.4	0.79	2.2	0.26

e. Tidal Response - The unusually large tide range in the greater Bay of Fundy area has been attributed in part to the relationship between physical dimensions and the frequency of tidal oscillation. Construction of a tidal power project at Cobscook Bay would likely have some impact on raising tide levels of the surrounding water. Only through further study could this effect be quantified (Section 4).

f. Water Quality - Reduced currents within the operating pool area will result in decreased vertical mixing which in turn will give rise to increased thermal stratification and greater seasonal variations in water temperature. The greatest temperature change would likely occur at the surface layer with a smaller change observed at the deep layer. There is a strong possibility that some amount of ice cover would develop on the pool during the winter months. Little temperature change would be expected outside of the pool area.

The mean surface salinity of the operating pool would likely be reduced. Bottom salinities would likely be altered only slightly. Since there is relatively little freshwater inflow to Cobscook Bay it is not likely that significant stratification of fresh and saline waters would develop. If any of this type of stratification does develop, Dennys Bay is the most probable location since this has the largest freshwater inflow. Outside of the operating pool little change is expected except for the emptying and filling areas where some decreased salinity would occur.

The vigorous tidal mixing currently taking place in Cobscook Bay promotes dissolved oxygen levels near the super-saturation level. Under the proposed plans mixing in the operating pool will be decreased, and it is likely that dissolved oxygen levels in the deep basins of Cobscook Bay will be reduced.

Suspended sediment concentrations in the water column will increase during construction of the project. The main sources of this increased loading will be the suspension of materials being used to construct the embankment and the resuspension of bottom sediment in the vicinity of construction. This temporary increase in suspended sediment will likely promote a short term degradation of other measures of water quality.

Some permanent change in type and distribution of sediment could be expected. Reduced range of water levels and wind fetch should cause a decrease in shoreline erosion within the operating pool. Lower energy levels in the pool should cause more sediments to deposit, thus impacting the distribution of marine sediments. Some deposition of sediment at the mouths of freshwater inflows could be expected.

g. Conclusions - Construction of the proposed Cobscook Bay Tidal Power Project will significantly alter the hydrodynamic conditions currently existing in the bay. The tide range behind the barrier will be greatly reduced, the mean pool level will be raised, currents and velocities within the pool will be reduced, and less mixing will take place. The potential exists for some stratification of salinity, temperature, and dissolved oxygen, and some winter icing could occur. Levels of suspended sediment and associated degradation of overall water quality will occur during construction and long-range, sediment circulation and deposition patterns will be changed.

Fairly high velocity flow will occur through the filling gates and turbine outlets. This will impact the area outside and adjacent to the embankment structure. Little overall effect is expected on the open ocean away from the structure, however some small increase in tide level is likely due to the closing off of Cobscook Bay.

4. RECOMMENDATIONS FOR FUTURE STUDY

a. General - As previously stated, all data and conclusions presented in the previous sections have either been extracted from or based upon existing literature. No water quality oriented studies were conducted for this report. Therefore, only statements of a general nature could be made regarding effects of the proposed tidal power project. More quantitative predictions can only be made through more detailed study.

In this section recommendations for the acquisition of baseline data necessary for the characterization of existing conditions and for partial input to the development of predictive models is outlined. The types of modeling required is explained. The recommendations and the benefits to be derived from this effort are then summarized in a discussion.

b. Baseline Data Collection - The collection of sufficient baseline data is a necessity in order to accurately characterize existing conditions within the bay and to assist in the calibration of any physical or computer model which may be used to simulate future conditions. In the following paragraphs the basic types of baseline data required will be discussed.

The physical characteristics of Cobscook Bay must be well documented, and accurate bathymetric data must be developed. This informtion will prove essential in the development of physical and mathematical models.

Sufficient tide gages should be established within Cobscook Bay to confirm the results of previous studies and to develop a full understanding of how the bay responds to the changing tide. The direction and magnitude of tidal currents should be documented for all parts of the bay during at least four times throughout the tide cycle, including spring and neap tides. Currents at surface and lower levels should be measured in order to describe the movement of the entire water column.

Profiles of dissolved oxygen, salinity, pH, and temperature should be developed throughout Cobscook Bay. A sufficient number of profiles should be measured in order to typify conditions in each of the subbays of Cobscook Bay. Profiles indicative of at least four points during the tide cycle should be gathered during spring, summer, and fall seasons.

Surface water samples should be taken within the bay for total coliform and fecal coliform bacteria at four times during the tide cycle during spring, summer, and fall. Additionally, surface samples for turbidity, pesticides, and PCB's should be gathered.

Spring, summer and fall samples should also be gathered throughout the bay from about six levels in the water column. These should be taken at four points in the tide cycle. Analyses performed should include: total suspended solids, volatile suspended solids, organic nitrogen, ammonia nitrogen, nitrate plus nitrite nitrogen, total phosphorus, mercury, lead, cadmium and selenium.

It is estimated that approximately 26 stations would be needed for water quality profiles, and 18 of these would be sampled for detailed chemical analyses. Seven stations in the vicinity of the proposed embankments would be used for the analysis of bottom sediments.

During construction, the resuspension of bottom sediments will take place. Therefore the characteristics of these sediments should be assessed. Tests to be performed should include: visual classification, sieve analysis, hydrometer, apparent specific gravity, pH, chemical oxygen demand, total kjeldahl nitrogen, oil and grease, percent volatile solids, radioactivity, arsenic, cadmium, copper, lead, mercury, nickel, vanadium, zinc, chromium, PCB's, DDT, and C-H-N ratio for silts and clays only.

Aerial photographs or other means should be utilized to determine the amount of icing, if any, that takes place on the bay during the winter months. Since some icing would be expected during post construction conditions this comparison could prove valuable.

c. Modeling - Future conditions in Cobscook Bay cannot be accurately predicted without the aid of modeling. Because of the extremely dynamic situation existing in the bay, the complex geometry and extreme tide range, no "off the shelf" computer model can be utilized to make definitive predictions.

It is recommended that a physical model of Cobscook Bay be developed. This model will be constructed and calibrated using data gathered in the previously mentioned baseline studies and other supplemental data. This model would be capable of simulating the action of tides in the bay. Currents, mixing, and stratification could be predicted.

A mathematical model would then be developed based upon the physical hydrodynamic model. The use of a mathematical model would allow for the variation of operating schemes and project layout. Many different simulations for varying conditions could take place using the mathematical model. This would not be practical using the physical model.

Additionally some separate type of modeling effort, likely mathematical, will have to be conducted to determine the amount of increase in tide levels which could be expected in the Bay of Fundy and the Gulf of Maine as a result of blocking off Cobscook Bay. It is not felt that a substantial increase will occur, however, this question should be addressed.

d. Discussion - In the preceding sections recommendations for the collection of baseline data have been made. These include bathymetric, tidal, and water quality data. Only through a data collection program such as this can existing conditions in Cobscook Bay be fully understood. Additional recommendations have been made advocating the development of physical and mathematical models to be used to determine future water quality conditions within the bay after construction of the project. Another mathematical modeling effort will likely be required to determine the effect construction of the tidal power project will have on tides in the Bay of Fundy and Gulf of Maine. The only way accurate predictions of future conditions can be made is through adoption of a program such as this.

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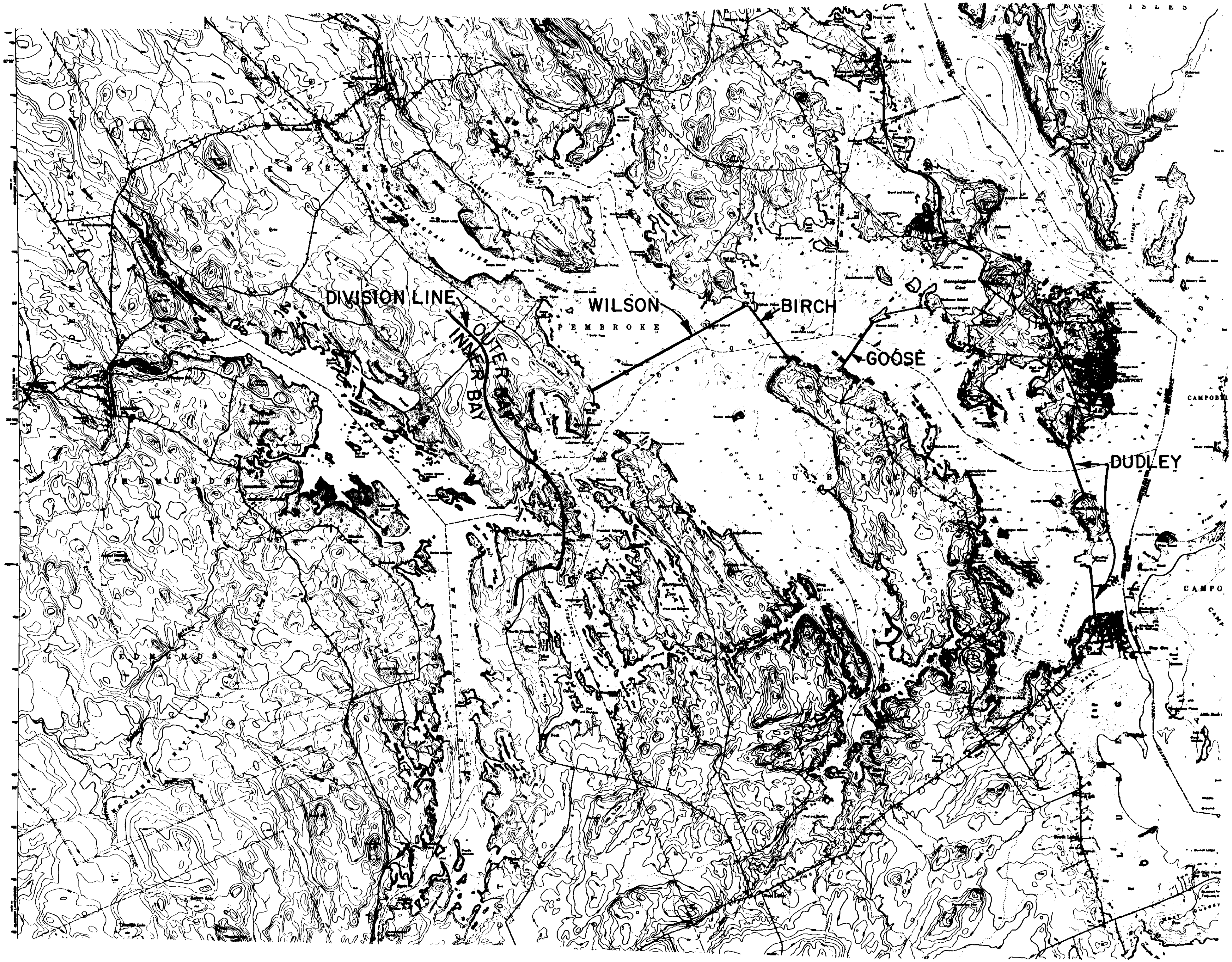
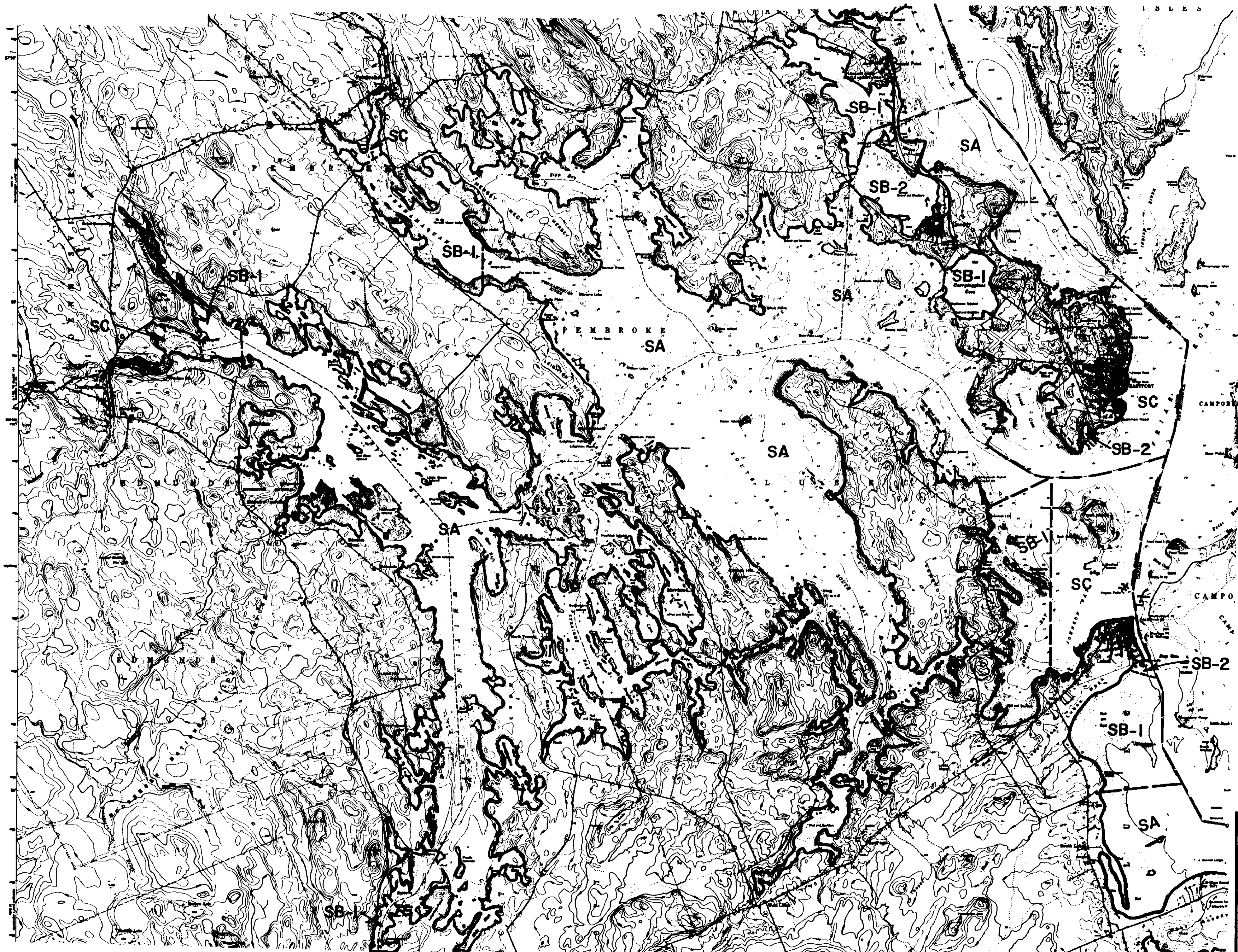


COBSCOOK BAY
TIDAL POWER PROJECT
ALTERNATIVE DIKE ALIGNMENTS
NEW ENGLAND DIVISION WALTHAM, MASS.
JUNE 1980

PLATE I



COBSCOOK BAY AREA

MARINE WATER QUALITY CLASSIFICATION BY DEPARTMENT OF ENVIRONMENTAL PROTECTION

STATE OF MAINE

OCTOBER 1977

PLATE 2

The following tables have been extracted from the 1980 Maine Coastal Characterization Study, prepared by the U.S. Fish and Wildlife Service. These tables provide some specific information on the resources found in Region 6 of the characterization study. Topics include mammals, waterfowl, wetlands, herptiles, and deer and black bear harvest data. These tables provide an overview of wildlife resources in Cobscook Bay. A resource map of the Cobscook Bay area has also been included.

Table 1 Acreages and Percentages of Intertidal Marine Habitats in Region 6 of the Coastal Characterization Area. (USFWS Coastal Characterization Study, 1980).

	Habitat type					Total intertidal marine subsystem
	Aquatic bed	Beach/bar	Flat	Reef	Rocky shore	
Acres	1318	1245	7982	26	4225	14,795
%	21	31	37	20	19	24

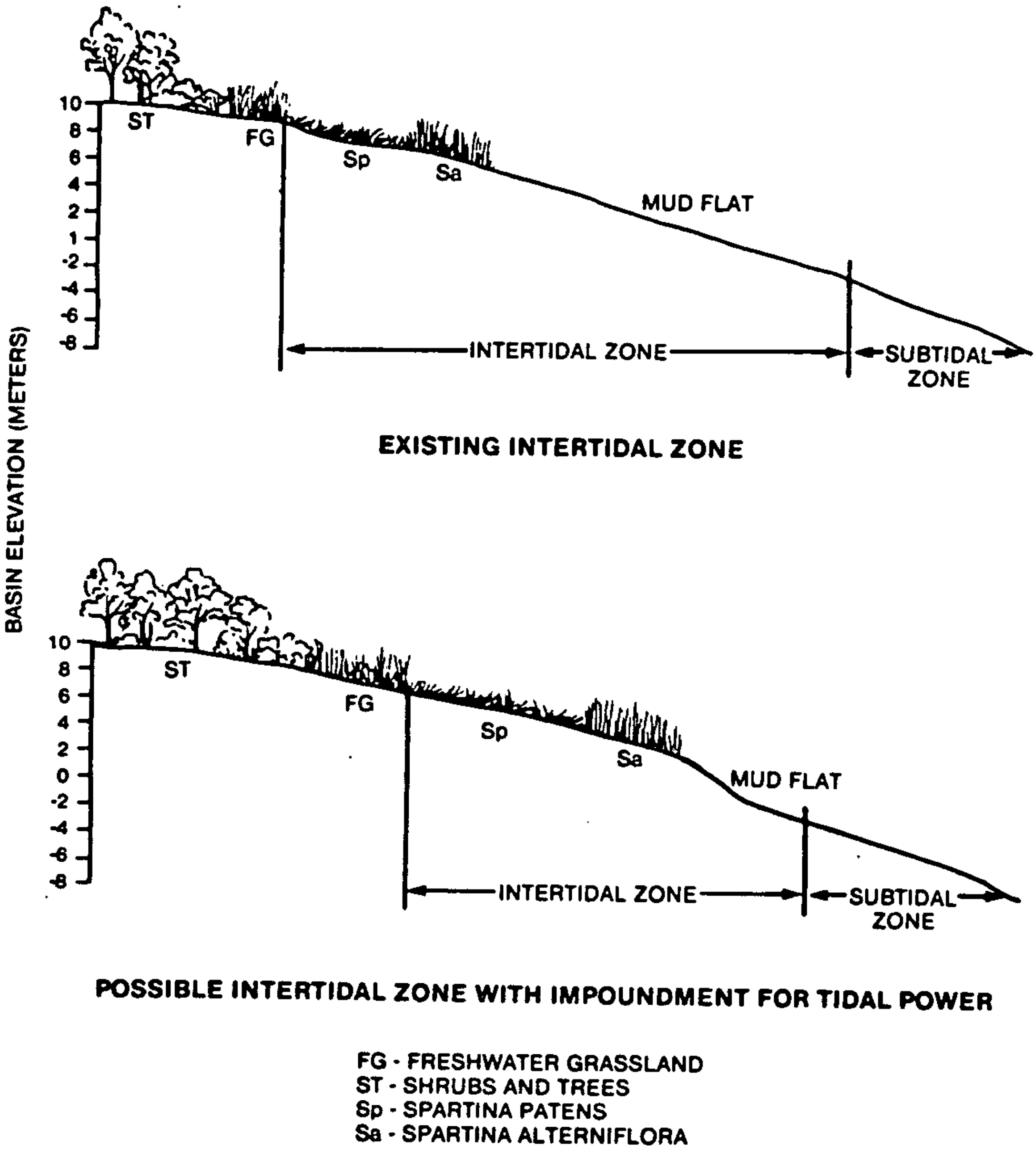


Figure 1 Conceptual effect of a new tidal regime on a generalized intertidal zone (Hodd 1977).

NATIONAL WETLANDS INVENTORY MAP LEGEND

WETLAND SYSTEM AND SUBSYSTEM

- System
  - Subsystem

- M Marine
  - 1 Subtidal
  - 2 Intertidal
- E Estuarine
  - 1 Subtidal
  - 2 Intertidal
- P Palustrine
  - No Subsystem
- R Riverine
  - 1 Tidal
  - 2 Lower Perennial
  - 3 Upper Perennial
  - 4 Intermittent
- L Lacustrine
  - 1 Limnetic
  - 2 Littoral
- U Upland

WETLAND CLASS AND SUBCLASS

- Class
  - Subclass
- OW Open Water/Unknown Bottom
- RB Rock Bottom
  - 1 Bedrock
  - 2 Boulder
- UB Unconsolidated Bottom
  - 1 Cobble/Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- SB Streambed
  - 1 Cobble/Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- BB Beach/Bar
  - 1 Cobble/Gravel
  - 2 Sand
- FL Flat
  - 1 Cobble/Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
  - 5 Vegetated Pioneer
  - 6 Vegetated Non-pioneer
- RS Rocky Shore
  - 1 Bedrock
  - 2 Boulder
  - 3 Vegetated Non-pioneer
- RF Reef
  - 1 Coral
  - 2 Mollusc
  - 3 Worm
- AB Aquatic Bed
  - 1 Submergent Algal
  - 2 Submergent Vascular
  - 3 Submergent Moss
  - 4 Floating - Leaved
  - 5 Floating
  - 6 Unknown Submergent
  - 7 Unknown Surface
- EM Emergent
  - 1 Persistent
  - 2 Nonpersistent
  - 3 Narrow-leaved Nonpersiste:
  - 4 Broad-leaved Nonpersisten:
  - 5 Narrow-leaved Persistent
  - 6 Broad-leaved Persistent
- ML Moss/Lichen
  - 1 Moss
  - 2 Lichen
- SS Scrub/Shrub
  - 1 Broad-leaved Deciduous
  - 2 Needle-leaved Deciduous
  - 3 Broad-leaved Evergreen
  - 4 Needle-leaved Evergreen
  - 5 Dead
  - 6 Deciduous
  - 7 Evergreen
- FO Forested
  - 1 Broad-leaved Deciduous
  - 2 Needle-leaved Deciduous
  - 3 Broad-leaved Evergreen
  - 4 Needle-leaved Evergreen
  - 5 Dead
  - 6 Deciduous
  - 7 Evergreen

Table 2

TABLE 3

MAMMALS KNOWN TO OCCUR WITHIN THE USFWS COASTAL CHARACTERIZATION AREA, REGION 6, LISTED BY ORDER.

Insectivora	
Masked shrew	*Sorex cinereus*
Water shrew	*Sorex palustris*
Smokey shrew	*Sorex fumeus*
Thompson's pygmy shrew	*Microsorex hoyi*
Shorttail shrew	*Blarina brevicauda*
Hairytail mole	*Parascalops breweri*
Starnose mole	*Condylura cristata*
Chiroptera (Bats)	
Little brown myotis	*Myotis lucifugus*
Keen myotis	*Myotis keeni*
Small-footed myotis	*Myotis subulatus*
Silver-haired bat	*Lasionycteris noctivagans*
Big brown bat	*Eptesicus fuscus*
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Lagomorpha (Rabbits and Hares)	
Snowshoe hare	*Lepus americanus*
Rodentia	
Eastern chipmunk	*Tamias striatus*
Woodchuck	*Marmota monax*
Gray squirrel	*Sciurus carolinensis*
Red squirrel	*Tamiasciurus hudsonicus*
Southern flying squirrel	*Glaucomys volans*
Northern flying squirrel	*Glaucomys sabrinus*
Beaver	*Castor canadensis*
Deer mouse	*Peromyscus maniculatus*
White-footed mouse	*Peromyscus leucopus*
Boreal redback vole	*Clethrionomys gapperi*
Meadow vole	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethica*
Southern bog lemming	*Synaptomys cooperi*
Norway rat	*Rattus norvegicus*
House mouse	*Mus musculus*
Meadow jumping mouse	*Zapus hudsonius*
Woodland jumping mouse	*Napaeozapus insignis*
Porcupine	*Erethizon dorsatum*

TABLE 3 (CONT'D)

Carnivora	
Coyote	*Canis latrans*
Red fox	*Vulpes fulva*
Black bear	*Ursus americanus*
Raccoon	*Procyon lotor*
Ermine	*Mustela erminea*
Longtail weasel	*Mustela frenata*
Mink	*Mustela vison*
Striped skunk	*Mephitis mephitis*
River otter	*Lutra canadensis*
Bobcat	*Lynx rufus*
Artiodactyla (Even-toed ungulates)	
Whitetail deer	*Odocoileus virginianus*
Moose	*Alces alces*

TABLE 4

Average Annual Legal Harvest of White-tailed deer (1959 to 1977) and Black Bear (1969 to 1977) for Region 6.

White-tailed deer	
Total harvest	787.0
Deer killed/sq. mi.	1.4
Black bear	
Total harvest	8.0
Bear killed/100 sq. mi.	1.3

TABLE 5

HERPTILES FOUND IN REGION 6 OF THE USFWS
COASTAL CHARACTERIZATION STUDY WHICH INCLUDES
COBSCOOK BAY

Salamanders	
Blue-spotted salamander	*Ambystoma laterale*
Spotted salamander	*Ambystoma maculatum*
Red-spotted newt	*Notophthalmus viridescens viridescens*
Northern dusky salamander	*Desmognathus fuscus fuscus*
Red-backed salamander	*Plethodon cinereus cinereus*
Northern two-lined salamander	*Eurycea bislineata bislineata*
Frogs and toads	
American toad	*Bufo americanus*
Spring peeper	*Hyla crucifer*
Gray treefrog	*Hyla versicolor*
Bullfrog	*Rana catesbeiana*
Green frog	*Rana clamitans melanota*
Northern leopard frog	*Rana pipiens*
Pickerel frog	*Rana palustris*
Mink frog	*Rana septentrionalis*
Wood frog	*Rana sylvatica*
Turtles	
Snapping turtle	*Chelydra serpentina*
Wood turtle	*Clemmys insculpta*
Eastern painted turtle	*Chrysemyspicta picta*
Snakes	
Northern water snake	*Natrix sipedon sipedon*
Northern brown snake	*Storeria dekayi dekayi*
Red-bellied snake	*Storeria occipitomaculata*
Eastern garter snake	*Thamnophis sirtalis sirtalis*
Northern ringneck snake	*Diadophis punctatus edwardsi*
Northern black racer	*Coluber constrictor constrictor*
Smooth green snake	*Opheodrys vernalis*
Eastern milk snake	*Lampropeltis triangulum triangulum*

Table 6

RESIDENT WATERFOWL SPECIES OF THE COASTAL CHARACTERIZATION AREA, INCLUDING REGION 6
(USFWS Coastal Characterization Study, 1980)

COMMON NAME	SCIENTIFIC NAME[a]	RELATIVE ABUNDANCE[b] BREEDING	MIGRATION	WINTERING
Black duck	*Anas rubripes* (Brewster)	Abundant	Abundant	Abundant
Mallard	*Anas p. platyrhynchos* (Linnaeus)	Rare	Common	Common
Common goldeneye	*Bucephala clangula* (Linnaeus)	Rare	Abundant	Abundant
American eider	*Somateria mollissima dresseri* (Sharpe)	Abundant	Abundant	Abundant
Hooded merganser	*Lophodytes cucullatus* (Linnaeus)	Common	Common	Rare
American merganser	*Mergus merganser* (Linnaeus)	Common	Common	Common
Canada goose	*Branta c. canadensis* (Linnaeus)	Rare	Abundant	Common

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).

[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

Table 7

WINTERING WATERFOWL SPECIES OF THE COASTAL CHARACTERIZATION AREA, INCLUDING REGION 6
(USFWS Coastal Characterization Study, 1980)

COMMON NAME	SCIENTIFIC NAME[a]	RELATIVE ABUNDANCE[b] MIGRATION	WINTER
Greater scaup	*Aythya marila* (Linneaeus)	Common[c]	Common[c]
Bufflehead	*Bucephala albeola* (Linnaeus)	Abundant	Abundant
Old Squaw	*Clangula hyemalis* (Linnaeus)	Abundant	Abundant
Harlequin	*Histrionicus histrionicus* (Linnaeus)	Rare	Rare
King eider	*Somateria spectabilis* (Linnaeus)	Rare	Rare
White-winged scoter	*Melanitta deglandi* (Bonaparte)	Abundant	Abundant
Surf scoter	*Melanitta perspecillata* (Linnaeus)	Common	Common
Black scoter	*Melanitta nigra* (Linnaeus)	Common	Common
Red-breasted merganser	*Mergus serrator* (Lnnaeus)	Abundant	Abundant
Barrow's goldeneye	*Bucephala islandica* (Gmelin)	Rare	Rare

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).

[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

[c]Usually occurs in flocks exceeding 100 but rather erratic and limited distribution.

Table 8

BREEDING WATERFOWL SPECIES OF THE COASTAL CHARACTERIZATION AREA, INCLUDING REGION 6
(USFWS Coastal Characterization Study, 1980)

COMMON NAME	SCIENTIFIC NAME[a]	RELATIVE ABUNDANCE[b] BREEDING	MIGRATION
Wood duck	*Aix sponsa* (Linnaeus)	Common	Common
Ring-necked duck	*Aythya collaris* (Donovan)	Common	Common
Blue-winged teal	*Anas discors* (Linnaeus)	Common	Common
American green-winged teal	*Anas crecca carolinensis* (Gmelin)	Common	Common

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).

[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

Table 9

MIGRANT WATERFOWL SPECIES OF THE COASTAL CHARACTERIZATION AREA, INCLUDING REGION 6
(USFWS Coastal Characterization Study, 1980)

COMMON NAME	SCIENTIFIC NAME[a]	RELATIVE ABUNDANCE[b] MIGRATION
Whistling swan	Olor columbianus (Ord)	Rare
Brant	Branta bernicla hrota (Muller)	Common (spring)
White-fronted goose	Anser albifrons (Scopoli)	Rare
Lesser snow (blue) goose	Chen c. caerulescens (Pallas)	Rare
Greater snow goose	Chen caerulescens atlanticus (Kennard)	Abundant
Gadwell	Anas strepera (Linnaeus)	Rare
Pintail	Anas acuta (Linnaeus)	Common
European widgeon	Anas penelope (Linnaeus)	Rare
American widgeon	Anas americana (Gmelin)	Common
Northern Shoveller	Anas clypeata (Linnaeus)	Rare
Redhead	Aythya americana (Eyton)	Rare
Canvasback	Aythya valisneria (Wilson)	Rare (spring)
Lesser scaup	Aythya affinis (Eyton)	Common
Ruddy duck	Oxyura jamaicensis (Gmelin)	Common
Fulvous Whistling Duck	Dedroeygna bicolor (Vieillot)	Rare

[a]According to A.O.U. (1957, 1973a, 1973b, 1976)

[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

TABLE 10

Common and Occasional Breeding Migratory Terrestrial Birds in the Study Area.

Cooper's hawk	Accipiter cooperii
Broad-winged hawk	Buteo platypterus
Marsh hawk	Circus cyaneus
Osprey	Pandion haliaetus
Killdeer	Charadrius vociferus
American woodcock	Philohela minor
Common snipe	Capella gallinago
Black-billed cuckoo	Coccyzus erythropthalmus
Common nighthawk	Chordeiles minor
Chimney swift	Chaetura pelagica
Ruby-throated hummingbird	Archilochus colubris
Belted kingfisher	Megaceryle alcyon
Common flicker	Colaptes auratus
Yellow-bellied sapsucker	Sphyrapicus varius
Eastern kings bird	Tyrannus tyrannus
Great-crested flycatcher	Myiarchus crinitus
Eastern phoebe	Sayornis phoebe
Yellow-bellied flycatcher	Empidonax flaviventris
Alder flycatcher	Empidonax alnorum
Least flycatcher	Empidonax minimus
Eastern wood pewee	Contopus virens
Olive-sided flycatcher	Nuttallornis borealis
Tree swallow	Tridoprocne bicolor
Bank swallow	Riparia riparia
Barn swallow	Hirundo rustica
Cliff swallow	Petrochelidon pyrrhonota
Winter wren	Troglodytes troglodytes
Long billed marsh wren	Telmatodytes palustris
Gray catbird	Dumetella carolinensis
Brown thrasher	Toxostoma rufum
Wood thrush	Hylocichla mustelina
Hermit thrush	Hylocichla guttata
Swainson's thrush	Hylocichla ustulata
Veery	Hylocichla fuscescens
Ruby-crowned kinglet	Regulus calendula
Cedar waxwing	Bombycilla cedrorum
Solitary vireo	Vireo solitarius
Red-eyed vireo	Vireo olivaceus
Warbling vireo	Vireo gilvus
Black-and-white warbler	Mniotilta varia
Tennessee warbler	Vermivora peregrina
Nashville warbler	Vermivora ruficapilla
Parula warbler	Parula americana
Yellow warbler	Dendroica petechia
Cape may warbler	Dendroica tigrina
Black-throated green warbler	Dendroica virens
Black-throated blue warbler	Dendroica caerulescens
Blackburnian warbler	Dendroica fusca
Chestnut-sided warbler	Dendroica pensylvanica
Bay-breasted warbler	Dendroica castanea
Magnolia warbler	Dendroica magnolia

TABLE 10 (Cont'd)

Palm warbler	Dendroica palmarum
Ovenbird	Seiurus aurocapillus
Northern water-thrush	Seiurus noveboracensis
Common yellow-throat	Geothlypis trichas
Wilson's warbler	Wilsonia pusilla
Canada warbler	Wilsonia canadensis
American redstart	Setophaga ruticilla
Bobolink	Dolichonyx oryzivorus
Eastern meadowlark	Sturnella magna
Red-winged blackbird	Agelaius phoeniceus
Rusty blackbird	Euphagus carolinus
Common grackle	Quiscalus qiuscula
Rose-breasted grosbeak	Pheucticus ludovicianus
Savannah sparrow	Passerculus sandwichensis
Sharp-tailed sparrow	Ammospiza caudacuta
Vesper sparrow	Pooecetes gramineus
Chipping sparrow	Spizella passerina
Swamp sparrow	Melospiza georgiana

TABLE 11

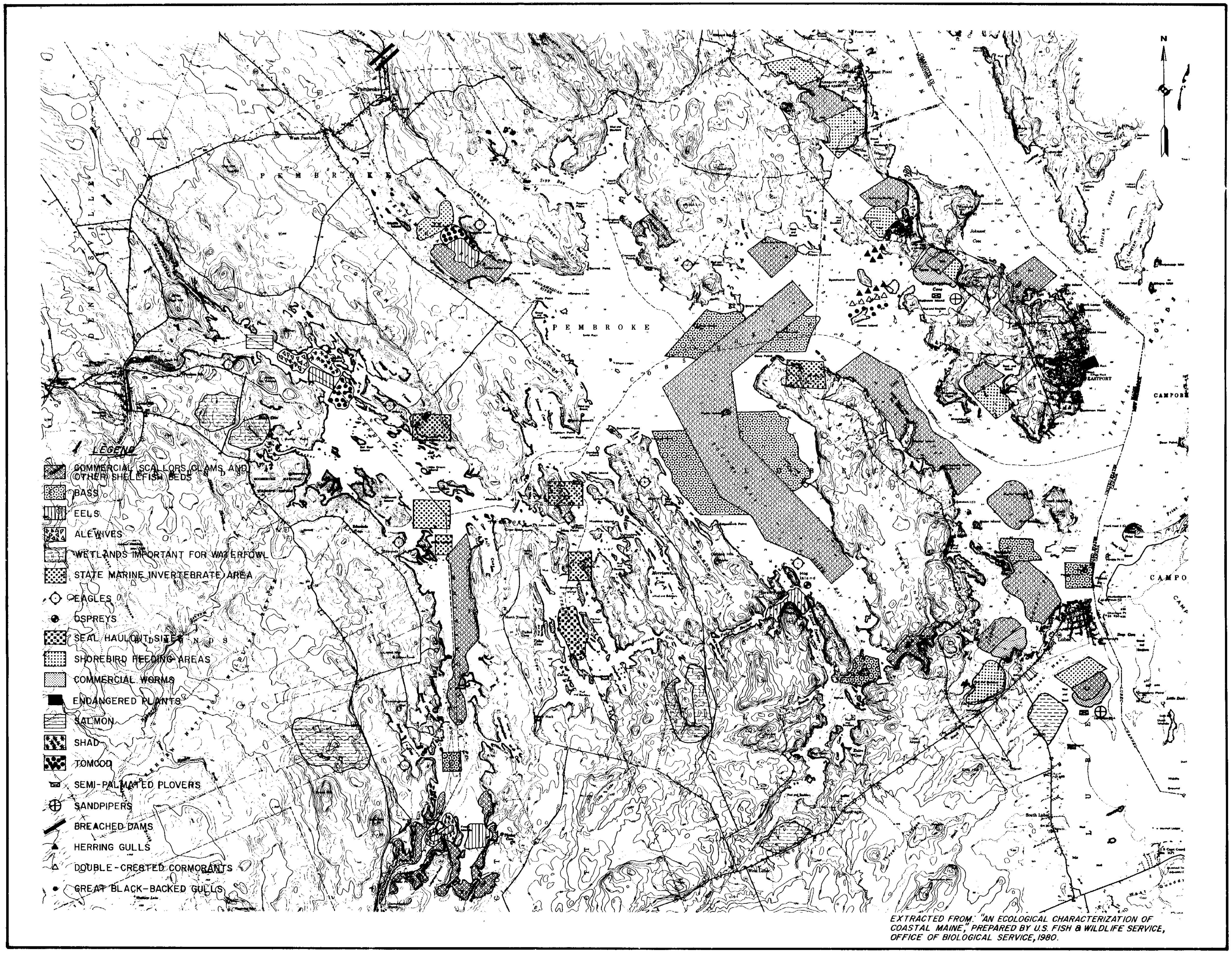
Common and Occasional Permanent Resident Terrestrial Birds in the Study Area

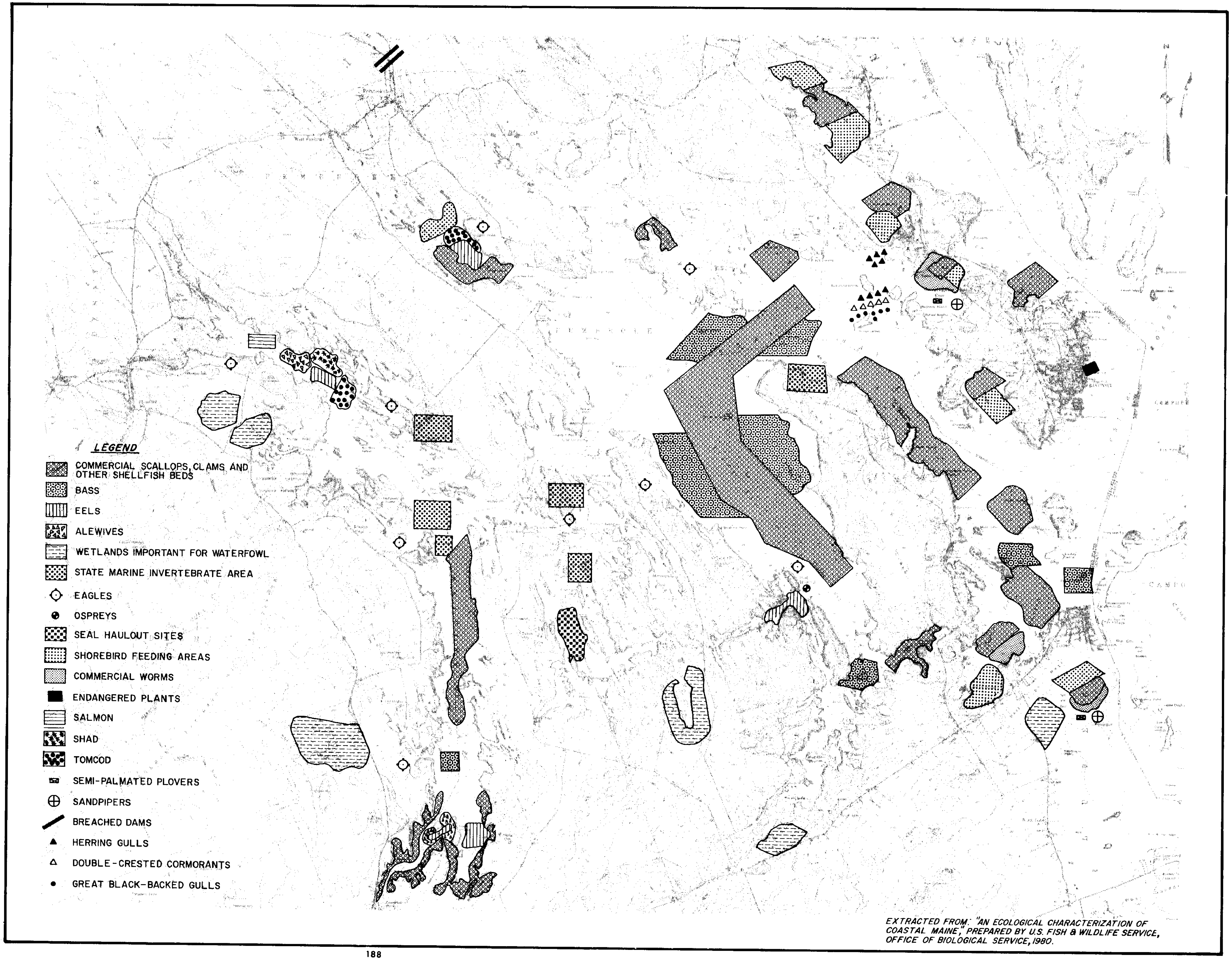
Kestrel	Falco sparverius
Spruce grouse	Canachites canadensis
Bald eagle	Haliaeetus leucocephalus
Ruffed grouse	Bonasa umbellus
Rock dove	Columba livia
Mourning dove	Zenaidura macroura
Barred owl	Strix varia
Hairy woodpecker	Picoides villosus
Downy woodpecker	Picoides pubescens
Blue jay	Cyanocitta cristata
Gray jay	Perisoreus canadensis
Common raven	Corvus corox
Common crow	Corvus brachyrhynchos
Black-capped chickadee	Parus atricapillus
Boreal chickadee	Parus hudsonicus
White-breasted nuthatch	Sitta carolinensis
Red-breasted nuthatch	Sitta canadensis
Brown creeper	Certhia familiaris
American robin	Turdus migratorius
Golden-crowned kinglet	Regulus satrapa
Starling	Sturnus vulgaris
Yellow-rumped warbler	Dendroica coronata
House sparrow	Passer domesticus
Brown-headed cowbird	Molothrus oter
Evening grosbeck	Hesperiphona vespertina
Purple finch	Carpodacus purpureus
Pine siskin	Spinus pinus
American goldfinch	Spinus tristis
Dark-eyed junco	Junco hyemalis
White-throated sparrow	Zonotrichia albicollis
Song sparrow	Melospiza melodia

TABLE 12

Common Non-Breeding Migratory Terrestrial Birds in the Study Area

Gyrfalcon	*Falco rusticolus*
Peregrine falcon	*Falco peregrinus*
Merlin	*Falco columbarius*
American golden plover	*Pluvialis dominica*
Baird's sandpiper	*Erolia bairdii*
Buff-breasted sandpiper	*Tryngites subruficollis*
Whimbrel	*Numenius phaeopus*
Water pipit	*Anthus spinoletta*
White-crowned sparrow	*Zonotrichia leucophrys*
Fox sparrow	*Passerella iliaca*


LEGEND
COMMERCIAL SCALLOPS, CLAMS AND OTHER SHELLFISH BEDS
BASS
EELS
ALEWIVES
WETLANDS IMPORTANT FOR WATERFOWL
STATE MARINE INVERTEBRATE AREA
EAGLES
OSPREYS
SEAL HAULOUT SITES
SHOREBIRD FEEDING AREAS
COMMERCIAL WORMS
ENDANGERED PLANTS
SALMON
SHAD
TOMCOD
SEMI-PALMATED PLOVERS
SANDPIPERS
BREACHED DAMS
HERRING GULLS
DOUBLE-CRESTED CORMORANTS
GREAT BLACK-BACKED GULLS
N
PEMBROKE
EASTPORT
CAMPOBELLO
Lubec
EXTRACTED FROM: "AN ECOLOGICAL CHARACTERIZATION OF COASTAL MAINE," PREPARED BY U.S. FISH & WILDLIFE SERVICE, OFFICE OF BIOLOGICAL SERVICE, 1980.



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